DOCUMENT RESUME

ED 246 252 CE 039 293

AUTHOR	Harwick, Jim; Siebert, Leo
TITLE	General Industrial Electronics. Oklahoma Trade and Industrial Education.
INSTITUTION	Oklahoma State Board of Vocational and Technical Education, Stillwater. Curriculum and Instructional Materials Center.; Oklahoma State Dept. of Vocational and Technical Education, Stillwater. Div. of Trade and Industrial Education.
PUB DATE	84
NOTE	586p.; For related documents, see ED 228 475 and CE 039 291-292.
AVAILABLE FROM	Curriculum and Instructional Materials Center, Oklahoma State Board of Vocational and Technical Education, 1500 West Seventh Avenue, Stillwater, OK 74074.
PUB TYPE	Guides - Classroom Use - Guides (For Teachers) (052)
EDRS PRICE	MF03 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	Behavioral Objectives; Classroom Techniques; Competency Based Education; Core Curriculum; Criterion Referenced Tests; Educational Strategies; *Electric Circuits; *Electronic Equipment; *Electronics; Equipment Maintenance; Equipment Utilization; Guidelines; *Industrial Personnel; Instructional Materials; Job Skills; Job Training; Learning Activities; Postsecondary Education; Secondary Education; Semiconductor Devices; State Curriculum Guides; Teaching Methods; *Technical Education; Trade and Industrial Education; Transistors
IDENTIFIERS	*Solid State (Electronics)

ABSTRACT

This curriculum guide, part of a series of curriculum guides dealing with industrial electricity and electronics, is designed for use in teaching a course in general industrial electronics. Covered in the first half of the guide are units on the following electronic components: semiconductors, solid-state diodes, bipolar transistors, and special semiconductor devices. The second half of the guide includes units on amplifier, power-supply, filtering, oscillator, multi-vibrator, and integrated circuits. Each instructional unit contains some or all of the following: performance objectives, suggested activities, information sheets, transparency masters, assignment sheets, job sheets, tests, and answers to the test and assignment sheets. (MN)

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General Industrial Electronics

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Curriculum and Instructional Materials Center

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Printed in the United States of America by the
State Department of Vocational and Technical Education
Stillwater, Oklahoma 74074

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GENERAL INDUSTRIAL ELECTRONICS

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FOREWORD

In Oklahoma, vocational educators have a basic belief that quality vocational programs require the use of sound instructional materials. A comprehensive approach with a quality treatment served as the primary objective when the Oklahoma State Department of Vocational and Technical Education, Curriculum and Instructional Materials Center began development of educational products for industrial technology. Materials now exist for several specialty fields, including pneumatics, hydraulics, industrial electricity, and industrial electronics. This volume, *General Industrial Electronics,* supplements *Introduction to Industrial Electricity-Electronics.* For students interested in the industrial electronics field, this volume prepares them for further study in the other two electronics volumes in the industrial technology program: *Applied Industrial Electronics: Sensors and Logic Systems* and *Applied Industrial Electronics: Power Control and Electronic Troubleshooting.*

Industry representatives, educators, and technical specialists collaborated closely to produce these materials in the hope that students will gain the knowledge and skills required in industrial electronics through practical learning experiences. Coupled with the instructor's own methods and expertise, these materials should prove to be a valuable asset for an industrial electronics program.

It is our sincere wish that *General Industrial Electronics* and the other manuals in this series will contribute to the development of a competent, safety-conscious work force in the industrial electronics trade.

Francis Tuttle, Director
Oklahoma State Department of
Vocational and Technical Education

Ivan Armstrong, State Supervisor
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Oklahoma State Department of
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PREFACE

The purpose of *General Industrial Electronics* is to acquaint students with the electronic components and circuits commonly used in industrial applications. The curriculum materials have been designed for use in full-time secondary and post-secondary classes, as well as part-time adult classes. The material is easily adaptable to open-entry, open-exit programs to allow students to progress at their individual paces.

A skilled instructor will be able to supplement, personalize, and localize this material to meet specific training needs. The design of the material allows the different topics to be presented in a variety of sequences and even permits the use of part of a unit of instruction at a given time. The "Use of this Publication" section will greatly aid the instructor and student in getting the most from these materials.

Bob Patton, Coordinator
Curriculum and Instructional
Materials Center
Oklahoma State Department of
Vocational and Technical Education

ACKNOWLEDGEMENTS

Any project as comprehensive and involved as this guideline for teaching industrial electronics, requires the contributions of a great number of people; and we are thankful for the tremendous support we have received in the development of this book. First, we are grateful to the Oklahoma State Department of Vocational and Technical Education under the direction of Dr. Francis Tuttle and especially to the industrial technology advisory committee for recognizing the need for these instructional materials.

We worked closely with two of the CIMC assistant coordinators, Greg Pierce and Joyce Sawatzky, who trained us and guided us during the writing process. The primary review committee consisted of several qualified instructors and industrial experts whose contributions were invaluable. The committee included

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Cecil Hendrick
Maintenance General Foreman
National Standard Company
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Raymond S. Todish
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Mercury Marine
Stillwater, Oklahoma

Jim Wilson
Assistant Superintendent of Adult
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Indian Meridian Area Vo-Tech School
Stillwater, Oklahoma

After the writing was completed, several vocational training programs field-tested these materials. Instructors involved in the field-test then met to review the results and suggest revisions. The final draft of these materials owes much to these instructors and industry people who took the time and showed the patience to use the field-test copy of this manual. The committee that reviewed the field-test results included

Charles Herndon
Electronics Instructor
Tulsa County Area Vo-Tech School
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Industrial Electronics Consultant
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Billy E. Bolechala
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We owe a great deal of gratitude to the many people involved in the production process. Robert Hilley served as the project coordinator during the production phase of this project at the CIMC. The entire editorial staff, under Terra McCluskey and her successor, Terri Barnes, did an excellent job of reviewing the content and format and getting the final copy ready for printing; thank you, Sue Buck, Sue Feasley, Marla Norman, Susan Walker, and Jerry Weir. The various drafts of the manuscript were ably produced by Judy DeVaughan of the CIMC secretarial staff, who prepared the rough drafts, and by the phototypesetters in the Communication Center under the direction of Jenny Fowler. Special thanks to Dona Landreth, Rose Primeaux, Gari Sha Robinson, and Allison MacLaughlin.

The Art Department, under Neil Tarvin, provided the excellent illustrations and graphics that accompany the text. We are grateful especially to Nancy Hilley and Dana Welborne who did the majority of the artwork. The quality of the published product is the result of the care and talents of the Print Shop personnel under the supervision of Noel Wilcoxson. To these and many others, we are extremely grateful because this book would not be possible without the combined efforts of everyone involved.

It is our sincere wish that these materials be of value to instructors in industrial electronics programs and that they benefit those students who are pursuing careers in this vital and rewarding field.

Leo Siebert

Jim Harwick

USE OF THIS PUBLICATION

Instructional Units

General Industrial Electronics includes nine instructional units. A standard format was established in 1970 for development of instructional materials for all Oklahoma vocational teachers. This format includes eight basic components that form a unit of instruction: performance objectives, suggested activities for the teacher, information sheets, assignment sheets, job sheets, transparency masters, tests, and answers to tests and assignment sheets. Depending on the specific objectives, there may or may not be transparency masters, assignment sheets, and job sheets included in the unit of instruction.

All of the unit components "zero in" on measurable and observable learning outcomes. Teachers are encouraged to supplement, personalize, localize, and motivate with these materials in order to develop a complete teaching/learning process.

Units of instruction are designed for use in more than one lesson or class period of instruction. Careful study of each unit of instruction by the teacher will help him or her determine the following

A. Amount of material that can be covered in each class period
B. Skills that must be demonstrated
   1. Supplies and equipment needed
   2. Amount of practice needed
   3. Amount of class time needed for demonstrations
C. Supplementary materials, such as pamphlets and filmstrips, that must be ordered
D. Resource people who must be contacted

Performance Objectives (white pages)

Each unit of instruction is based on the performance needed for successful employment in an occupational area. Performance objectives are stated in two forms: unit objectives, stating the subject matter to be covered in a unit of instruction; and specific objectives, stating the performance necessary to reach the unit objective.

Since the objectives of the unit provide direction for the teaching/learning process, it is important that teachers and students have a common understanding of the intent of the objectives. Following is a list of performance terms, their meanings, and behavioral synonyms that may have been used in this material.

A. Name — The individual supplies a name for objects, events, or people

   Behavioral synonyms: Label, list, letter, record, reiterate, repeat, write

B. Identify — The individual selects a named, described, or pictured object by pointing to it, touching it, picking it up, or selecting it

   Behavioral synonyms: Select, mark, match, choose, judge

C. State a rule — The individual communicates a relationship or principle that could be used to solve problems or perform a task

D. Apply a rule — The individual supplies an answer to a problem by using a stated relationship or principle

Behavioral synonyms: Solve, calculate

E. Describe — The individual relates sufficient characteristics or properties of an object or event so that a second individual will be able to state what is being discussed

Behavioral synonyms: Define, discuss, interpret, recite, tell how, tell what happens when

F. Distinguish — The individual selects an object or event from two or more that are easily confused

Behavioral synonyms: Discriminate, differentiate

G. Order — The individual arranges three or more objects or events in a sequence based on a stated property

Behavioral synonyms: Arrange, sequence, list in order, classify, divide, isolate, sort

H. Construct — The individual makes a physical object, a verbal statement, or a drawing

(NOTE: *Construct* is used when the finished product or result is important.)

Behavioral synonyms: Draw, make, build, design, formulate, reproduce, transcribe, convert, put together, compile

I. Demonstrate — The individual performs several operations necessary to carry out a specified process

(NOTE: *Demonstrate* is used when it is desirable to watch the student perform a task, one of the highest levels of student performance.)

Behavioral synonyms: Show your work, show procedure, perform an experiment, perform the steps, operate, remove, replace, turn off/on, (dis)assemble, (dis)connect

The objectives should be provided for students and stressed throughout the teaching/learning process. This will help answer any questions concerning performance requirements for each instructional unit. The objectives can also help determine teaching strategies and instructional methods. Prepare for each unit by deciding how each objective can best be taught.

The objective sheet may also be used as a quick pretest to determine prior knowledge of students and to determine whether further study or activities are necessary. Teachers should feel free to modify, delete, or add objectives in order to meet the needs of the students and community. When changes in objectives are made, the teacher should remember to supply the needed information, assignment and/or job sheets, and criterion test items.

Suggested Activities (pink pages)

This component is included only in teacher material. The suggested activities page assists teachers during the preparation stage of the teaching/learning process by providing suggestions for delivery and/or presentation during the instructional process. Read the suggested activities before teaching the units to allow time to obtain supplemental materials, prepare audiovisual materials, and contact outside resources. Duties of the teacher will vary according to the particular unit.

The references that are listed are ones used in the development of each unit. They should be used by the teacher to supplement her or his knowledge of the subject area or to help students with particular interests or occupational objectives in the area covered.

Information Sheet (green pages)

The information sheet provides "must know" content essential for meeting the cognitive (knowledge level) objectives of the unit. The information is written in a topical outline form and is keyed to the specific objectives.

Teachers will find that the information sheet serves as an excellent guide for presenting background knowledge necessary to develop the skills specified in the unit objective. The information sheet may also be used for coordination activities and advisory committees.

Students should read the information sheet before the information is discussed in class. Space is provided in margins for students and teachers to add notes that supplement, localize, personalize, or provide motivation for each unit.

Transparency Masters (white pages in teacher material and green in student material)

Transparency masters provide information in a special way. Transparencies direct the class's attention to the topic of discussion. Transparencies may present new information, or they may reinforce information presented in the information sheet. They are particularly effective when identification is necessary. Make transparencies and place them in the notebook where they will be immediately available for use.

Assignment Sheets (brown pages)

Assignment sheets give students a chance at problem solving, self-assessment, and/or practical experience with the information. They assist students in the application of knowledges that are necessary prerequisites to skill development. These may be given to the student for completion in class or used for homework assignments. Answer sheets are provided when appropriate and can be used by the student and/or teacher for checking student progress.

Job Sheets (blue pages)

Job sheets are another important segment of a unit of instruction. The job sheets provide a list of equipment, tools, and materials needed to complete a manipulative or psychomoter skill. They describe a step-by-step procedure needed to complete each task or job. Diagrams, photographs, and illustrations are provided to assist students in achieving the skill.

Instruments in job sheets are not in order of use. The order of use should be taught in the classroom. In this way, students will not depend entirely on job sheets for instrument setup.

A teacher should demonstrate to students the procedures outlined in each job sheet. Furthermore, the teacher needs to localize the job sheet according to the equipment and supplies available in the local lab or shop situation. Job sheets also furnish potential employers with a picture of the skills being taught and the performances they might reasonably expect from a person who has had this vocational instruction.

Tests (yellow pages)

This component provides criterion-referenced evaluation of every objective listed in the unit of instruction. It is crucial to note that both paper/pencil and performance objectives must be evaluated.

The tests may be written or oral. It is recommended that the tests be divided into shorter tests covering three or four objectives at a time and given soon after those objectives have been covered. A selection of questions from the units covered may be used for final tests at the end of each term if desired. If objectives have been added, deleted, or modified, be sure to make the changes on the test.

The acceptable response on a unit test, 85 percent in most units, may be raised or lowered to fit the topic or students' ability levels. The percentage applies to the overall score, not to each individual question. The final unit grade should be obtained by using the paper/pencil score along with evaluations of student demonstrations of the desired skills.

Answers to Test and Assignment Sheets (pink pages)

These components are designed to assist the teacher in evaluation of student performances.

Page Numbering

Each publication from the Curriculum and Instructional Materials Center is assigned a specific abbreviation. For example, *General Industrial Electronics* has been abbreviated GIE. The units are then numbered consecutively within each section. An example of a page number is GIE-1-A. Since CIMC publications are loose leaf, this system of page numbering was adopted so that pages from different manuals would not get mixed up.

Methods of Disseminating Material

Material may be given out a unit or page at a time to keep the material before the students always new. Some teachers ask students to furnish a three-ring binder for the units. This is convenient for taking the materials home to study. Upon completion, each unit is then placed in a larger binder. The large binders may be purchased at cost from the CIMC. Some teachers store the materials by units in filing cabinets or boxes until needed. All the units may be given out at once if desired.

For best results, provide student materials for each student. Student materials contain everything but the test answers, answers to assignment sheets, and suggested activities. All tests are collated at the back of student material and should be removed and stored until needed. Students should be allowed to take their materials home at the end of the year.

Teaching Methods

It is a challenge to keep students motivated. Supplement the objectives by providing the "why," personal experiences, and current information. Prepare for each unit by deciding how each objective can best be taught. Allow students to become involved in preparing and planning.

Competency Profiles

Competency profiles are folders used to document student performance. The profile contains a list of the specific job competencies that should be achieved prior to leaving the training program.

SEMICONDUCTOR BASICS
UNIT I

UNIT OBJECTIVE

After completing this unit, the student should be able to interpret symbols and abbreviations associated with semiconductors; compare atomic characteristics of insulators, semiconductors, and conductors; and identify the anode and cathode of solid-state diodes. The student will show this knowledge by completing the assignment sheets, job sheet, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with semiconductors to their correct definitions.
2. Match abbreviations associated with semiconductors to their correct interpretations.
3. Identify schematic symbols of common semiconductor devices.
4. State characteristics of electrons.
5. Match semiconductor terms to their correct electronic descriptions.
6. Name commonly used semiconductor materials.
7. Match semiconductor electrical characteristics to their correct explanations.
8. Compare atomic characteristics of insulators, semiconductors, and conductors.
9. Describe the effects of applied voltage to semiconductor materials.
10. Name types of semiconductor components.
11. Identify the anode and cathode of various devices.
12. Identify actual semiconductor components.
13. Demonstrate the ability to identify the anode and cathode of solid-state diodes, using an ohmmeter.

SEMICONDUCTOR BASICS
UNIT I

SUGGESTED ACTIVITIES

I. Suggested activities

   A. Make transparencies.

   B. Gather semiconductor devices of many sizes and shapes so that students may complete Assignment Sheet #2.

   C. Provide students with objective sheet.

   D. Discuss unit and specific objectives, relating the objectives to on-the-job experiences.

   E. Review "Atoms and Materials," Section B, Unit I in *Introduction to Industrial Electricity-Electronics*.

   F. Provide students with information, assignment, and job sheets.

   G. Discuss information and assignment sheets.

   H. Collect and display as many varied types of semiconductor devices as possible, pointing out similarities, differences, and terminals.

   I. Connect a diode to an ohmmeter; heat diode with a small flame or a soldering iron to show the effects of heat.

   J. Review "Meters," Section D, Unit I in *Introduction to Industrial Electricity-Electronics*.

   K. Demonstrate and discuss procedures outlined in the job sheet.

   L. Give test.

   M. Reteach and retest if necessary.

II. Instructional materials

   A. Objective sheet

   B. Suggested activities

   C. Information sheet

   D. Transparency masters

      1. TM #1 — Semiconductor Atomic Structure

SUGGESTED ACTIVITIES

2. TM #2 — Effects of Voltage Applied to n-Material
3. TM #3 — Effects of Voltage Applied to p-Material

E. Assignment sheets

1. Assignment Sheet #1 — Identify the Anode and Cathode of Various Devices
2. Assignment Sheet #2 — Identify Actual Semiconductor Components

F. Answers to assignment sheets

G. Job Sheet #1 — Identify the Anode and Cathode of Solid-State Diodes, Using an Ohmmeter

H. Test

I. Answers to test

III. Unit references

A. Alley, Charles L., and Kenneth W. Altwood. *Electronic Engineering*, 3rd ed. New York: John Wiley and Sons, Inc., 1973.

B. Chirlian, Paul M. *Electronic Circuits: Physical Principles, Analysis, and Design*. New York: McGraw-Hill Book Co., 1971.

C. *Graphic Symbols for Electrical and Electronics Diagrams.* New York: Institute of Electrical and Electronics Engineers, 1981.

D. Zbar, Paul B., and Joseph G. Sloop. *Electricity-Electronics Fundamentals*, 2nd ed. New York: McGraw-Hill Book Co., 1977.

SEMICONDUCTOR BASICS
UNIT I

INFORMATION SHEET

I. Terms and definitions

A. Anode — Part of an electronic device that collects electrons from within and eventually passes electrons to external circuitry; positive electrode (Assignment Sheet #1)

B. Bond — Linkage that holds atoms and molecules together

C. Cathode — Part of an electronic device into which electrons enter from the external circuit and are emitted within the device; negative electrode (Assignment Sheet #1)

D. Charge — Net effect of number of electrons in a mass; may be positive or negative

E. Conduction band — Position that outer-shell electrons occupy when they have enough energy to break away from the atom and flow as current

F. Energy gap — Difference between energy of electrons in their normal positions and energy electrons must have to move into a position where they can be separated from the atom

G. Leakage current — Small current that flows in the reverse direction during cutoff because of unwanted impurities

H. Negative temperature coefficient — Characteristic of a device or material such that an increase in temperature results in a decrease in resistance

I. Semiconductor — Material that is neither a good conductor nor a good insulator but possesses specific conduction characteristics

(NOTE: Semiconductor conduction characteristics are adjusted by mixing other materials, called *impurities* or *extrinsic materials*, with the pure or intrinsic materials.)

J. Thermal runaway — Process in which a component or circuit becomes overheated and allows excessive current to flow, which in turn creates more heat, until destruction occurs

K. Valence band — Normal position outer-shell electrons occupy around the atom

L. Valence electrons — Electrons in specific orbits most distant from center of atom; they assume primary responsibility for bonding atoms and are charge carriers

INFORMATION SHEET

II. Abbreviations associated with semiconductors and their interpretations

(NOTE: The following abbreviations are often found on schematic drawings and in technical references such as maintenance manuals. They are also printed on devices as well as on material containers. It is generally assumed by manufacturers, drafters, and technical writers that technicians know the meanings of these abbreviations.)

A. Ge — Germanium

B. Se — Selenium

C. Si — Silicon

D. LED — Light-emitting diode

E. SCR — Silicon-controlled rectifier

F. FET — Field-effect transistor

G. IC — Integrated circuit

H. XSTR — Transistor

I. XTL — Crystal

J. RTD — Resistive thermal device

K. LCD — Liquid-crystal display

L. E — Emitter

M. C — Collector

N. B — Base

O. t° — Temperature effect

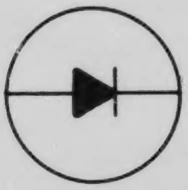
INFORMATION SHEET

III. Schematic symbols of common semiconductor devices (Figures 1-8)

(NOTE: Symbols shown are those recommended by the Institute of Electrical and Electronics Engineers in its April, 1981, edition of *Graphic Symbols for Electrical and Electronics Diagrams.*)

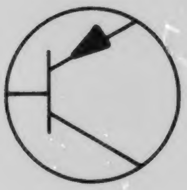
A. Solid-state diode or crystal rectifier (CR)

FIGURE 1



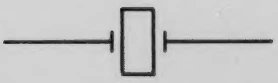
B. Bipolar transistor (XSTR)

FIGURE 2



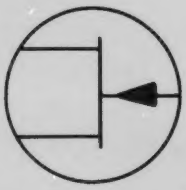
C. Crystal (XTL)

FIGURE 3



D. Field-effect transistor (FET)

FIGURE 4

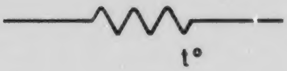


INFORMATION SHEET

E. Thermistor

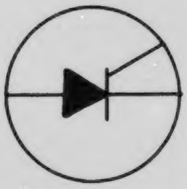
(NOTE: A thermistor is also called a *resistive thermal device* [RTD].)

FIGURE 5



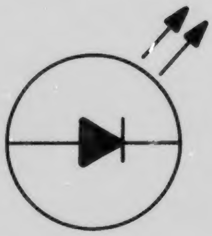
F. Silicon-controlled rectifier (SCR)

FIGURE 6



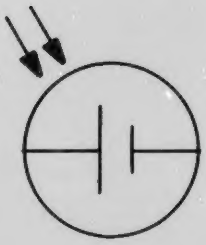
G. Light-emitting diode (LED)

FIGURE 7



H. Photocell

FIGURE 8



INFORMATION SHEET

IV. Characteristics of electrons

(NOTE: Electrons always have charge. They may or may not exhibit bonding.)

A. Have charge

B. Exhibit bonding

V. Semiconductor terms and their electronic descriptions

A. Acceptor atom — Atom having fewer outer-shell electrons than required for bonding

B. Charge carriers — Electrons, holes, or both, depending on the substance, its purity, and the molecular bonds

C. Covalent bonding — Atoms or molecules held together by the electrons they share in order to meet the charge requirements

D. Donor atom — Atom having more outer-shell electrons than required for bonding

E. Doping — Process of combining either donor or acceptor atoms with crystal atoms to make a semiconductor device

F. Excess electron — Electron not tightly held by the atom because it is in excess of those needed to meet the bond requirement

G. Hole — Position within a molecular structure where an electron is needed to complete the bond requirement; considered for some purposes as if it were a particle itself

H. Ion — Atom or molecule having deficiency or excess of electrons

I. Majority carriers — Electrons or holes, depending on which are the most in number; result of intentional doping of impurities during manufacture of the semiconductor; account for the conductivity of the device

J. Minority carriers — Electrons or holes, depending on which are the least in number; contributed by unwanted impurities and by excessive heat; account for reverse leakage current

K. n-material — Semiconductor material with more outer-shell electrons than required by the bond

L. p-material — Semiconductor material with too few outer-shell electrons to meet the molecular-bond requirements

INFORMATION SHEET

VI. Commonly used semiconductor materials (Transparency #1)

A. Silicon

B. Germanium

C. Selenium

VII. Semiconductor electrical characteristics

A. Leakage — Unwanted impurities create minority carriers, resulting in imperfect performance

B. Negative temperature coefficient — Heat frees electrons normally held by bonds of the structure

C. Thermal runaway — Overheating frees electrons that create additional heat until the device is destroyed

D. Sensitivity to excessive current — Current flow can dislodge electrons normally held by bonds of the structure

E. Sensitivity to excessive voltage — High voltage can dislodge electrons normally held by bonds of the structure

VIII. Atomic characteristics of insulators, semiconductors, and conductors (Table 1)

(NOTE: Careful study of the following chart will reveal characteristics of materials discussed elsewhere in this unit. Note that insulators, for example, which are crystalline in form, hold their electrons rigidly in the structure. Notice also that the energy required to release electrons from semiconductors can be heat, light, or pressure. All these forms of energy are used by devices made to detect temperature, light, or pressure.)

TABLE 1

Characteristics	Insulators	Semiconductors	Conductors
Atomic hold on outer-shell electrons	Securely held within the atomic structure	Moderately held within the atomic structure	Loosely held within the atomic structure
Energy required to separate electrons	Destructive amounts of energy are required to cause massive flow of electrons	Moderate values of heat, pressure, light, and voltage can cause the electrons to separate	Very little voltage is needed to cause electron flow
Temperature coefficient	Unimportant until temperatures reach the point of material destruction	Negative temperature coefficient; heat aids electron flow	Positive temperature coefficient; heat impedes electron flow

INFORMATION SHEET

IX. Effects of applied voltage to semiconductor materials (Transparencies #2 and #3)

A. n-material

1. Electrons are majority carriers and flow toward positive connection

2. Holes are minority carriers and flow toward negative connection

(NOTE: The concept of hole-flow is the conventional approach to explaining semiconductor operation. The effects are as if holes existed. However, holes are merely a concept and not actual subatomic particles.)

B. p-material

1. Holes are majority carriers and flow toward negative connection

2. Electrons are minority carriers and flow toward positive connection

(NOTE: Regardless of the material, holes flow toward negative polarities and electrons always flow toward positive polarities.)

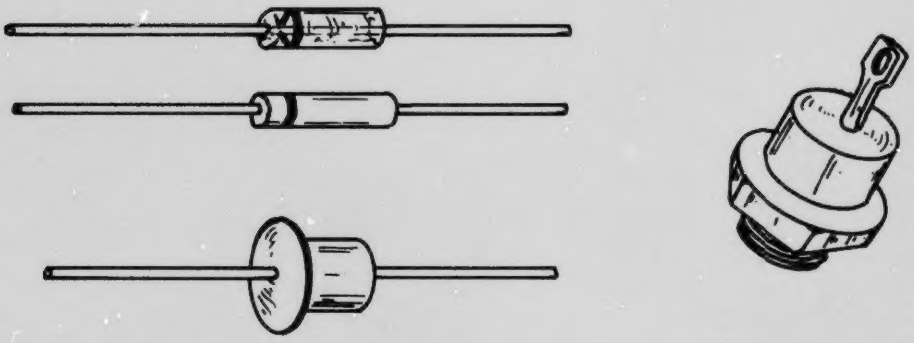
X. Types of semiconductor components (Figures 9-12; Assignment Sheets #1 and #2)

A. Diodes

(NOTE: Diodes are two-terminal devices.)

EXAMPLES:

FIGURE 9

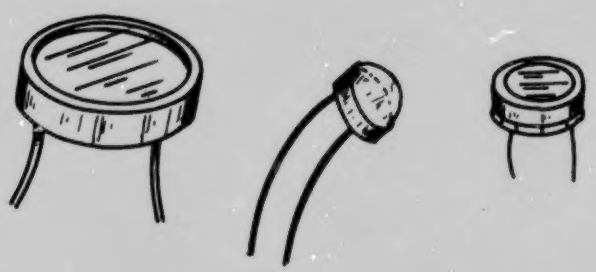


B. Photo devices

(NOTE: Photo devices have windows to admit light.)

EXAMPLES:

FIGURE 10

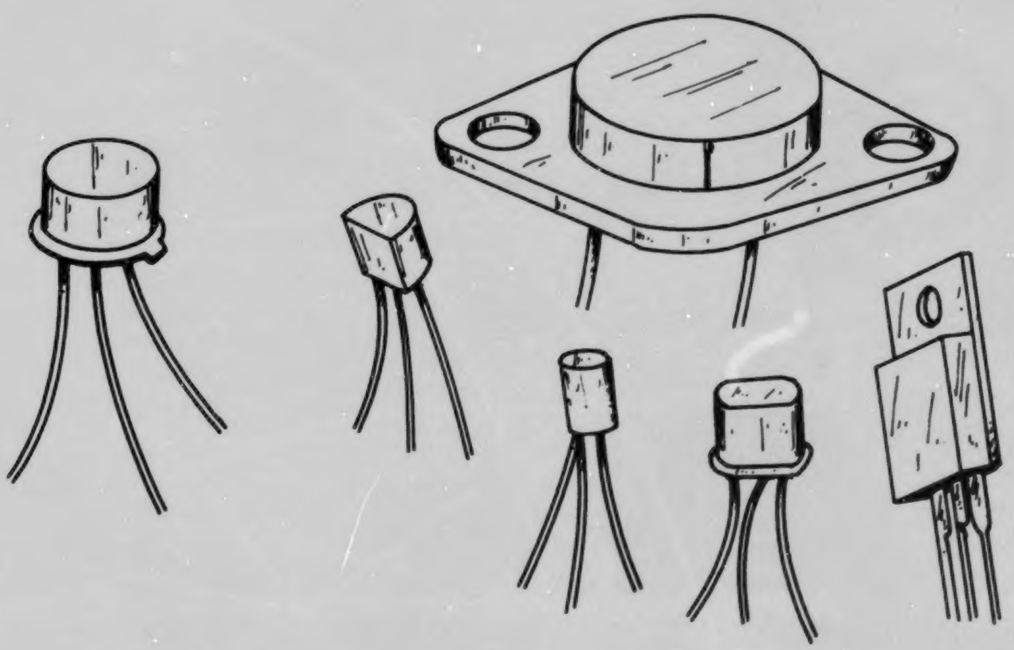


C. Transistors

(NOTE: Transistors usually have at least three terminals or leads. The power transistor case is usually the collector lead.)

EXAMPLES:

FIGURE 11



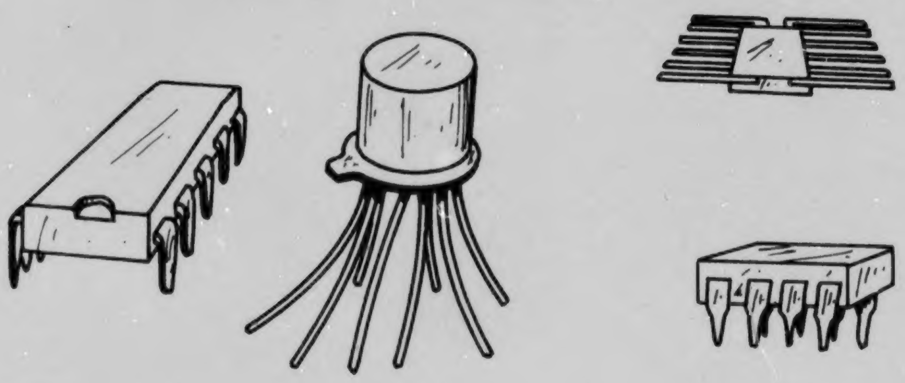
INFORMATION SHEET

D. Integrated circuits

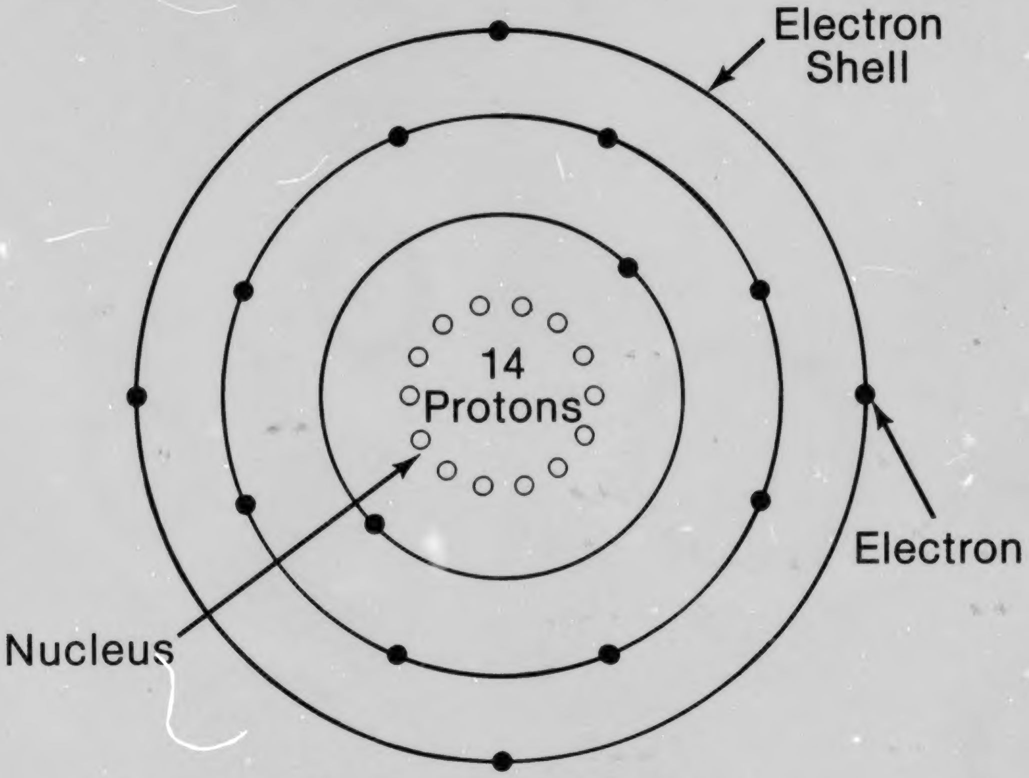
(NOTE: Integrated circuits usually have eight or more leads.)

EXAMPLES:

FIGURE 12



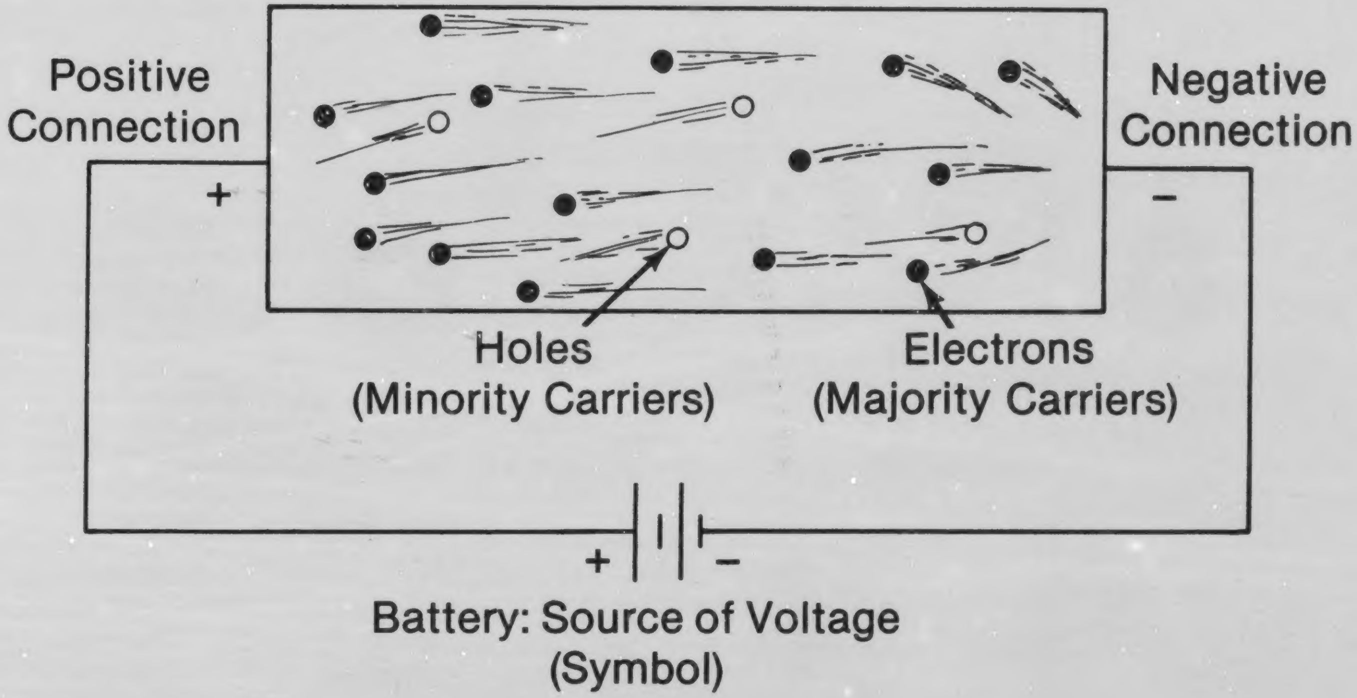
Semiconductor Atomic Structure


Electron Shell
14 Protons
Electron
Nucleus

Typical Semiconductor Atom
(Silicon)

Material	Protons	Total Electrons	Outer-Shell Electrons
Germanium	32	32	4
Silicon	14	14	4
Selenium	34	34	6

Effects of Voltage Applied to n-Material



Positive Connection

+

Negative Connection

–

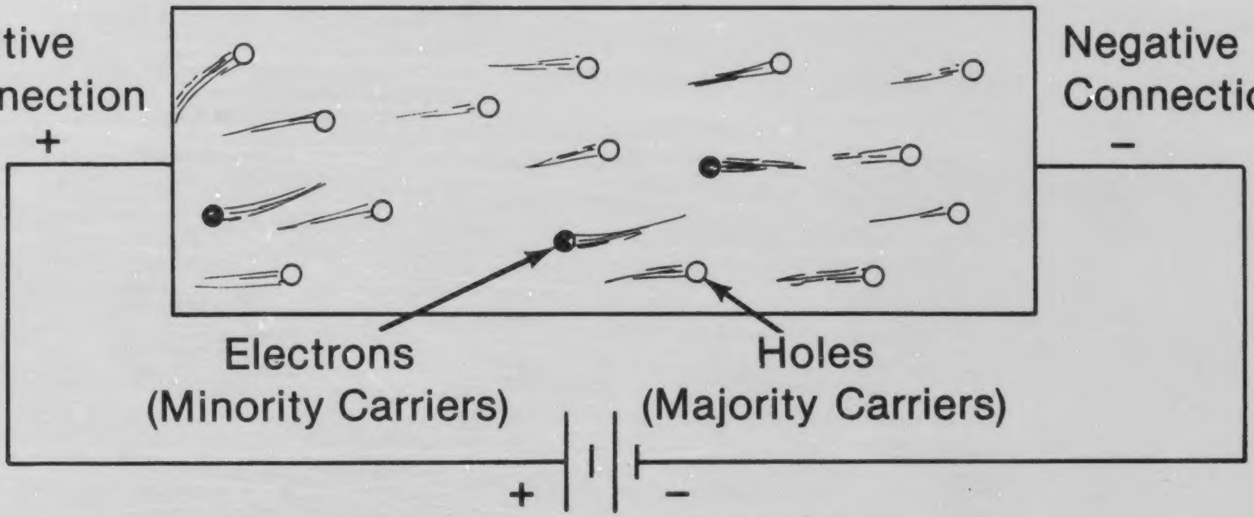
Holes
(Minority Carriers)

Electrons
(Majority Carriers)

+ –

Battery: Source of Voltage
(Symbol)

Effects of Voltage Applied to p-Material



Positive Connection
+

Negative Connection
–

Electrons
(Minority Carriers)

Holes
(Majority Carriers)

+ –

Battery: Source of Voltage
(Symbol)

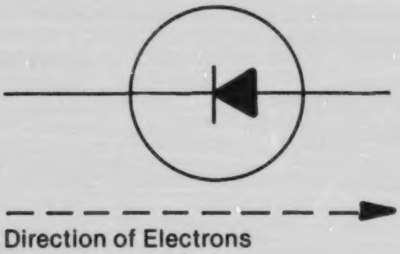
SEMICONDUCTOR BASICS
UNIT I

ASSIGNMENT SHEET #1 — IDENTIFY THE ANODE AND CATHODE OF VARIOUS DEVICES

NAME ______________________________ SCORE ______________

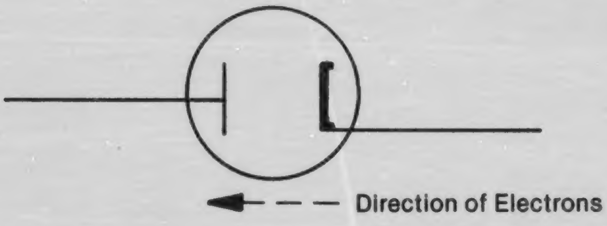
The terms *anode* and *cathode* are used to identify the parts of diodes, vacuum-tube devices, and electrochemical apparatus. The anode is always the part that collects the electrons from within the device and passes them to the external circuit. The cathode is the part that emits electrons throughout the device as they are supplied from the outside circuit. In a solid-state diode, electrons flow as shown below and on the next page. The cathode accepts electrons and transmits them to the anode, which then passes them back to the external circuit.

Identify the cathode and anode of each of the following devices by observing the external or internal electron flow and writing the correct term in the space provided. Show your work to your instructor when you finish.



Solid-State Diode or Semiconductor Diode

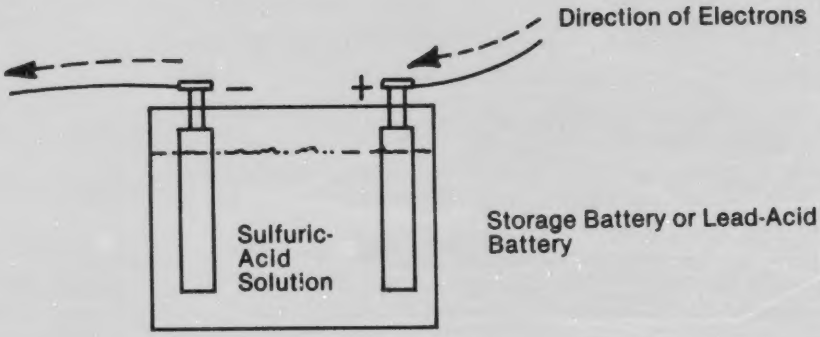
A. 1.______________________ 2.______________________



Vacuum-Tube Diode or Electron Tube

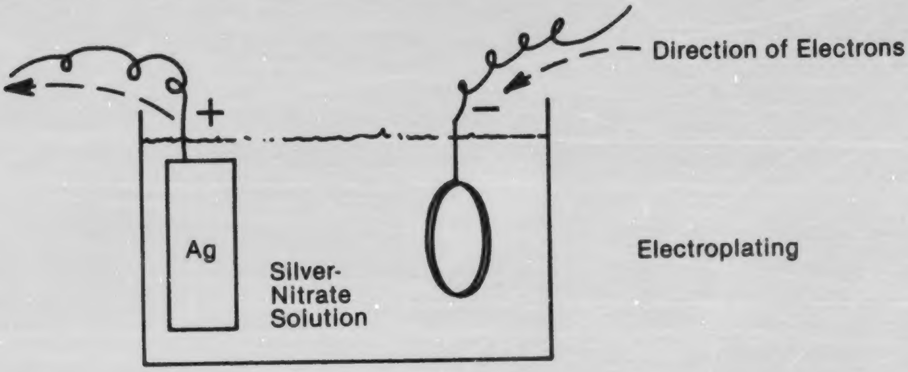
B. 1.______________________ 2.______________________

ASSIGNMENT SHEET #1


Direction of Electrons
−
+
Sulfuric-Acid Solution

Storage Battery or Lead-Acid Battery

C. 1.______________________________ 2.______________________________


Direction of Electrons
+
−
Ag
Silver-Nitrate Solution

Electroplating

D. 1.______________________________ 2.______________________________

SEMICONDUCTOR BASICS
UNIT I

ASSIGNMENT SHEET #2 — IDENTIFY ACTUAL SEMICONDUCTOR COMPONENTS

NAME ____ SCORE ________________

There are many sizes and shapes of semiconductor components. Many component types look identical to other types. Transistors, for example, often look exactly like small silicon-controlled rectifiers. Many diodes look like resistors. The only way a technician can be certain which component is which is to check the part number against a reference-book listing. There are, however, general shapes and characteristics that help technicians identify components. Diode part numbers often begin with the prefix "1N" and transistor part numbers often begin with "2N." Diodes are two-terminal devices, and transistors have at least three terminals. Integrated circuits have from six to sixteen or more leads.

Review Information Sheet, Section X, and then ask your instructor to provide you with a mixed group of transistors, diodes, and integrated circuits of all types and sizes.

Label the three sheets of blank paper that follow (one sheet for each type), and without using other references, attempt to separate the components onto the sheets of paper according to their type. Have your instructor check your work.

ASSIGNMENT SHEET #2

ASSIGNMENT SHEET #2

ASSIGNMENT SHEET #2

SEMICONDUCTOR BASICS
UNIT I

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

A. 1. Cathode

2. Anode

B. 1. Anode

2. Cathode

C. 1. Anode

2. Cathode

D. 1. Anode

2. Cathode

Assignment Sheet #2 — Evaluated to the satisfaction of the instructor

SEMICONDUCTOR BASICS
UNIT I

JOB SHEET #1 — IDENTIFY THE ANODE AND CATHODE OF SOLID-STATE DIODES, USING AN OHMMETER

I. Equipment and materials

A. Ohmmeter, or digital multimeter, with test leads

B. Solid-state rectifier diode

II. Procedure

(NOTE: It is assumed that the student is familiar with the basic operation of a multimeter.)

A. Select ohms function on ohmmeter

B. Connect test leads to the proper multimeter jacks to measure ohms

C. Select power range for semiconductor testing

D. Zero adjust meter if necessary

E. Set OHMS ADJUST if using a standard meter-movement instrument

F. Measure across diode and record resistance (R), noting the polarity of test leads with respect to leads or terminals of diode

R = ____________ with negative lead to ____________ diode terminal

G. Reconnect test leads across diode in reverse direction

H. Record resistance reading and polarity

R = ____________ with negative lead to ____________ diode terminal

I. If the two readings did not vary substantially, change ohmmeter range and repeat steps F, G, and H until two dissimilar readings are observed; record

1. R = ____________ with negative lead to ____________ diode terminal

JOB SHEET #1

2. R = ______________ with negative lead to ______________ diode terminal

   (NOTE: The lowest ohms reading indicates that the diode's cathode was connected to the negative, or black test lead, of the ohmmeter. When that low resistance reading was taken, the lead connected to the anode was then the positive, or red lead. When the ohmmeter indicated the high resistance measurement, the negative test lead was connected to the diode's anode and the positive test lead was connected to the diode's cathode.)

J. Once you are certain about which diode terminals are the cathode and anode, record the following diode measurements:

The low resistance reading was ______________ ohms when the meter ______________ test lead was connected to the diode terminal identifiable by (sketch if necessary) ______________. The resistance reading opposite of the above was ______________ ohms.

(NOTE: Have the instructor check your work.)

K. Put away equipment and materials

SEMICONDUCTOR BASICS
UNIT I

TEST

NAME ______________________________ SCORE ______________

1. Match terms associated with semiconductors to their correct definitions. Write the correct numbers in the blanks. Definitions continue on the following page.

_____a. Part of an electronic device into which electrons enter from the external circuit and are emitted within the device; negative electrode

_____b. Part of an electronic device that collects electrons from within and eventually passes electrons to external circuitry; positive electrode

_____c. Normal position outer-shell electrons occupy around the atom

_____d. Position that outer-shell electrons occupy when they have enough energy to break away from the atom and flow as current

_____e. Difference between energy of electrons in their normal positions and energy electrons must have to move into a position where they can be separated from the atom

_____f. Small current that flows in the reverse direction during cutoff because of unwanted impurities

_____g. Linkage that holds atoms and molecules together

_____h. Characteristic of a device or material such that an increase in temperature results in a decrease in resistance

_____i. Process in which a component or circuit becomes overheated and allows excessive current to flow, which in turn creates more heat, until destruction occurs

1. Bond
2. Valence electrons
3. Thermal runaway
4. Negative temperature coefficient
5. Semiconductor
6. Charge
7. Leakage current
8. Valence band
9. Conduction band
10. Energy gap
11. Anode
12. Cathode

TEST

______j. Material that is neither a good conductor nor a good insulator but possesses specific conduction characteristics

______k. Electrons in specific orbits most distant from center of atom; they assume primary responsibility for bonding atoms and are charge carriers

______l. Net effect of number of electrons in a mass; may be positive or negative

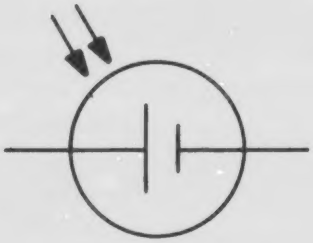
2. Match abbreviations associated with semiconductors to their correct interpretations. Write the correct numbers in the blanks.

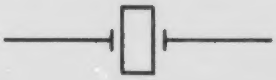
______a.	Light-emitting diode	1. C
______b.	Field-effect transistor	2. B
______c.	Crystal	3. E
______d.	Resistive thermal device	4. LCD
______e.	Silicon-controlled rectifier	5. RTD
______f.	Liquid-crystal display	6. XTL
______g.	Transistor	7. XSTR
______h.	Selenium	8. IC
______i.	Integrated circuit	9. FET
______j.	Germanium	10. SCR
______k.	Collector	11. LED
______l.	Emitter	12. Si
______m.	Silicon	13. Se
______n.	Base	14. t°
______o.	Temperature effect	15. Ge

TEST

3. Identify schematic symbols of common semiconductor devices. Write the correct names in the blanks.

Solid-state diode or crystal rectifier (CR)
Bipolar transistor (XSTR)
Crystal (XTL)
Field-effect transistor (FET)
Thermistor
Silicon-controlled rectifier (SCR)
Light-emitting diode (LED)
Photocell



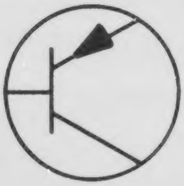


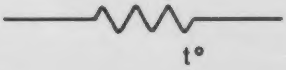
a. ______________________________

____

b. ______________________________

____





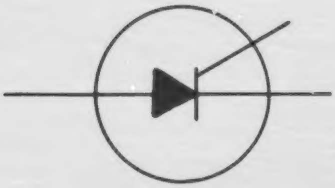
c. ______________________________

____

d. ______________________________

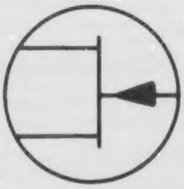
____

TEST



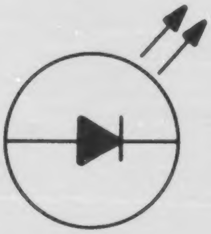
e. ______________________________

____



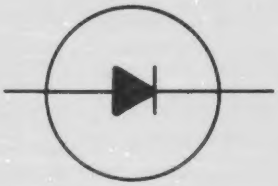
f. ______________________________

____



g. ______________________________

____



h. ______________________________

____

4. State characteristics of electrons.

a. ____

b. ____

5. Match semiconductor terms to their correct electronic descriptions. Write the correct numbers in the blanks. Terms and definitions continue on the following page.

_____a. Atom or molecule having deficiency or excess of electrons

_____b. Atoms or molecules held together by the electrons they share in order to meet the charge requirements

_____c. Electrons, holes, or both, depending on the substance, its purity, and the molecular bonds

1. Covalent bonding
2. Ion
3. Change carriers

TEST

______d. Process of combining either donor or acceptor atoms with crystal atoms to make a semiconductor device

______e. Atom having fewer outer-shell electrons than required for bonding

______f. Position within a molecular structure where an electron is needed to complete the bond requirement; considered for some purposes as if it were a particle itself

______g. Electron not tightly held by the atom because it is in excess of those needed to meet the bond requirement

______h. Atom having more outer-shell electrons than required for bonding

______i. Semiconductor material with more outer-shell electrons than required by the bond

______j. Semiconductor material with too few outer-shell electrons to meet the molecular-bond requirements

______k. Electrons or holes, depending on which are the least in number; contributed by unwanted impurities and by excessive heat; account for reverse leakage current

______l. Electrons or holes, depending on which are the most in number; result of intentional doping of impurities during manufacture of the semiconductor; account for the conductivity of the device

4. Excess electron
5. Hole
6. Minority carriers
7. Majority carriers
8. p-material
9. n-material
10. Donor atom
11. Acceptor atom
12. Doping

6. Name commonly used semiconductor materials.

a. ______________________________

b. ______________________________

c. ______________________________

TEST

7. Match semiconductor electrical characteristics to their correct explanations. Write the correct numbers in the blanks.

_____a. Overheating frees electrons that create additional heat until the device is destroyed

_____b. Current flow can dislodge electrons normally held by bonds of the structure

_____c. Unwanted impurities create minority carriers, resulting in imperfect performance

_____d. Heat frees electrons normally held by bonds of the structure

_____e. High voltage can dislodge electrons normally held by bonds of the structure

1. Leakage
2. Negative temperature coefficient
3. Thermal runaway
4. Sensitivity to excessive current
5. Sensitivity to excessive voltage

8. Compare atomic characteristics of insulators, semiconductors, and conductors. Complete the following chart by writing the correct answers in the blanks.

Characteristics	Insulators	Semiconductors	Conductors
Atomic hold on outer-shell electrons	Securely held within the atomic structure	a. ______	Loosely held within the atomic structure
Energy required to separate electrons	b. ______	Moderate values of heat, pressure, light, and voltage can cause the electrons to separate	c. ______
Temperature coefficient	Unimportant until temperatures reach the point of material destruction	d. ______	Positive temperature coefficient; heat impedes electron flow

TEST

9. Describe the effects of applied voltage to semiconductor materials.

   a. n-material — ______________________________

   b. p-material — ______________________________

10. Name types of semiconductor components.

    a. ______________________________

    b. ______________________________

    c. ______________________________

    d. ______________________________

(NOTE: Test questions 11-13 list the assignment and job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

11. Identify the anode and cathode of various devices.

12. Identify actual semiconductor components.

13. Demonstrate the ability to identify the anode and cathode of solid-state diodes, using an ohmmeter.

SEMICONDUCTOR BASICS
UNIT I

ANSWERS TO TEST

1.

a.	12	g.	1
b.	11	h.	4
c.	8	i.	3
d.	9	j.	5
e.	10	k.	2
f.	7	l.	6

2.

a.	11	i.	8
b.	9	j.	15
c.	6	k.	1
d.	5	l.	3
e.	10	m.	12
f.	4	n.	2
g.	7	o.	14
h.	13		

3. a. Photocell
   b. Crystal (XTL)
   c. Bipolar transistor (XSTR)
   d. Thermistor
   e. Silicon-controlled rectifier (SCR)
   f. Field-effect transistor (FET)
   g. Light-emitting diode (LED)
   h. Solid-state diode or crystal rectifier (CR)

ANSWERS TO TEST

4. a. Have charge
   b. Exhibit bonding

5. a. 2
   b. 1
   c. 3
   d. 12
   e. 11
   f. 5
   g. 4
   h. 10
   i. 9
   j. 8
   k. 6
   l. 7

6. a. Silicon
   b. Germanium
   c. Selenium

7. a. 3
   b. 4
   c. 1
   d. 2
   e. 5

8. a. Moderately held within the atomic structure
   b. Destructive amounts of energy are required to cause massive flow of electrons
   c. Very little voltage is needed to cause electron flow
   d. Negative temperature coefficient; heat aids electron flow

9. Description should include the following
   a. n-material
      1) Electrons are majority carriers and flow toward positive connection
      2) Holes are minority carriers and flow toward negative connection

ANSWERS TO TEST

- b. p-material
  - 1) Holes are majority carriers and flow toward negative connection
  - 2) Electrons are minority carriers and flow toward positive connection

10. a. Diodes
    b. Photo devices
    c. Transistors
    d. Integrated circuits

11. Evaluated to the satisfaction of the instructor

12. Evaluated to the satisfaction of the instructor

13. Performance skills evaluated to the satisfaction of the instructor

SOLID-STATE DIODES
UNIT II

UNIT OBJECTIVE

After completing this unit, the student should be able to test for defective diodes and construct diode circuits to observe alternating-current and direct-current effects on semiconductor diodes. The student will show this knowledge by completing assignment sheets, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with solid-state diodes to their correct definitions.
2. Match abbreviations associated with solid-state diodes to their correct interpretations.
3. Identify solid-state diode symbols.
4. Identify common diode configurations.
5. Match diode materials to their correct characteristics.
6. Match types of diodes to their correct uses.
7. Distinguish between forward- and reverse-biased polarities.
8. Match parts of a semiconductor diode to their correct functions.
9. Label anode and cathode terminals on diodes and symbols.
10. Describe biasing effects on the pn junction.
11. Name reasons for diode failure.
12. Identify parts of diode characteristic curves.
13. Identify proper and improper diode installation techniques.
14. Demonstrate the ability to
    a. Construct a diode circuit for observing the effects of direct current on a semiconductor diode.
    b. Construct a diode circuit for observing the effects of alternating current on a semiconductor diode.

OBJECTIVE SHEET

c. Use an ohmmeter to determine the anode and cathode of diodes.

d. Use an ohmmeter to test for defective diodes.

e. Use a semiconductor tester to test for defective diodes.

SOLID-STATE DIODES
UNIT II

SUGGESTED ACTIVITIES

I. Suggested activities

   A. Make transparencies.

   B. Gather various types of diodes.

   C. Gather materials and equipment for job sheet demonstrations.

   D. Provide students with objective sheet.

   E. Discuss unit and specific objectives. State need for knowledge in each area.

   F. Provide students with information and assignment sheets.

   G. Discuss information and assignment sheets.

   H. Review appropriate material in "Fabricating Skills," Section F of *Introduction to Industrial Electricity-Electronics,* before students complete Assignment Sheet #1.

   I. Show various types of diodes to students and explain each, indicating cathode and anode terminals.

   J. Prepare materials for job sheets.

   K. Provide students with job sheets.

   L. Demonstrate and discuss procedures outlined in job sheets.

   M. Show students various diode application and mounting procedures.

   N. Give test.

   O. Reteach and retest if necessary.

II. Instructional materials

   A. Objective sheet

   B. Suggested activities

   C. Information sheet

SUGGESTED ACTIVITIES

D. Transparency masters

  1. TM #1 — Parts of a Semiconductor Diode
  2. TM #2 — Biasing Effects on the pn Junction
  3. TM #3 — Silicon-Diode Characteristic Curve
  4. TM #4 — Germanium-Diode Characteristic Curve
  5. TM #5 — Zener-Diode Characteristic Curve

E. Assignment sheets

  1. Assignment Sheet #1 — Identify Proper and Improper Diode Installation Techniques
  2. Assignment Sheet #2 — Determine the Cathode Terminal of Diodes and Symbols

F. Answers to assignment sheets

G. Job sheets

  1. Job Sheet #1 — Construct a Diode Circuit for Observing the Effects of Direct Current on a Semiconductor Diode
  2. Job Sheet #2 — Construct a Diode Circuit for Observing the Effects of Alternating Current on a Semiconductor Diode
  3. Job Sheet #3 — Use an Ohmmeter to Determine the Anode and Cathode of Diodes
  4. Job Sheet #4 — Use an Ohmmeter to Test for Defective Diodes
  5. Job Sheet #5 — Use a Semiconductor Tester to Test for Defective Diodes

H. Test

I. Answers to test

III. Unit references

A. Baer, Charles J. *Electrical and Electronics Drawing*, 3rd ed. New York: McGraw-Hill Book Company, 1973.

B. *Graphic Symbols for Electrical and Electronics Diagrams.* New York: Institute of Electrical and Electronics Engineers, 1981.

SUGGESTED ACTIVITIES

C. Grob, Bernard. *Basic Electronics,* 4th ed. New York: McGraw-Hill Book Company, 1977.

D. *Semiconductors: Operation and Replacement of Semiconductors.* Barrington, Illinois: TPC Training Systems, Division of Technical Publishing Company, 1977.

E. Shrader, Robert L. *Electronic Communication,* 3rd ed. New York: McGraw-Hill Book Company, 1975.

SOLID-STATE DIODES
UNIT II

INFORMATION SHEET

I. Terms and definitions

A. Ambient temperature — Temperature of air or liquid surrounding an electrical device

B. Breakdown voltage — Point in the semiconductor diode at which reverse bias breaks down the semiconductor device

(NOTE: This current surge can damage or destroy the diode.)

C. Characteristic curve — Chart showing effects of forward and reverse biasing of a semiconductor diode

D. Diode — Two-terminal (anode and cathode) device that exhibits easy movement of electrons from cathode to anode when proper voltage is applied but resists movement of electrons from anode to cathode

(NOTE: Depending upon the design of device, diode characteristics also vary according to voltage, current, heat, and light.)

E. Doping — Adding impurities to a pure semiconductor material

F. Excess electron — Extra electron in bonding structure of a semiconductor material; electron is free to move

G. High-voltage transients — Voltage spikes resulting from interferences in power distribution

H. n-material — Semiconductor material with more outer-shell electrons than required by the bond (Transparency #2)

I. p-material — Semiconductor material with too few outer-shell electrons to meet molecular-bond requirements (Transparency #2)

J. pn junction — Area where p- and n-type semiconductor materials interface (Transparency #1)

K. Potential barrier — Resistance to current flow at the pn junction of semiconductor materials; results from electrons and holes combining to form a neutral zone

L. Rectification — Conversion of alternating current to direct current

INFORMATION SHEET

M. Saturation point — Point beyond which an increase in voltage produces no additional increase in current flow

N. Temperature drift — Tendency of a circuit to change characteristics as its temperature changes

O. Threshold voltage — Point in the semiconductor diode at which forward-bias voltage overcomes potential barrier for sharp current increase

II. Abbreviations associated with solid-state diodes

A. CR — Crystal rectifier

(NOTE: In schematic drawings "CR" is used to denote virtually any type of solid-state diode.)

B. LED — Light-emitting diode

C. Si — Silicon

D. Ge — Germanium

E. λ — Greek letter lambda; signifies light

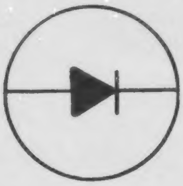
F. LCD — Liquid-crystal display

III. Solid-state diode symbols (Figures 1-9)

(NOTE: There are variations to diode symbols shown here, but usually the diode type can be recognized by symbolic clues. Symbols shown are those used by the Institute of Electrical and Electronics Engineers.)

A. General-purpose diode

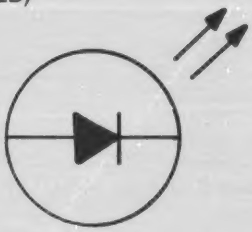
FIGURE 1



INFORMATION SHEET

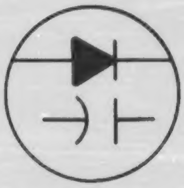
B. Light-emitting diode (LED)

FIGURE 2



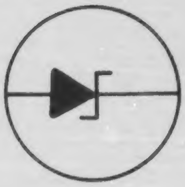
C. Varactor diode (varicap diode)

FIGURE 3



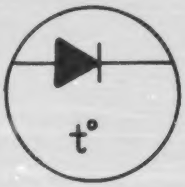
D. Zener diode

FIGURE 4



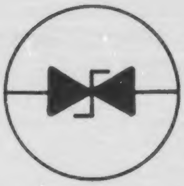
E. Temperature-compensating diode

FIGURE 5



F. Thyrector diode

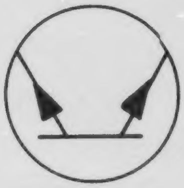
FIGURE 6



INFORMATION SHEET

G. Diac

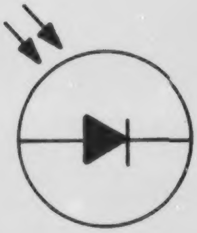
FIGURE 7



H. Photodiode

(NOTE: This symbol shows arrows representing light rays pointing *toward* the device; the LED shows arrows pointing *away* from the device.)

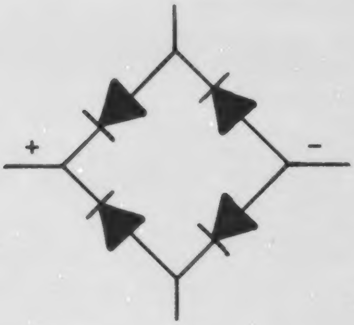
FIGURE 8



i. Full-wave diode-bridge rectifier

(NOTE: The "diode bridge" may be found in the circuit as four connected diodes, or it may be one component with four terminals.)

FIGURE 9



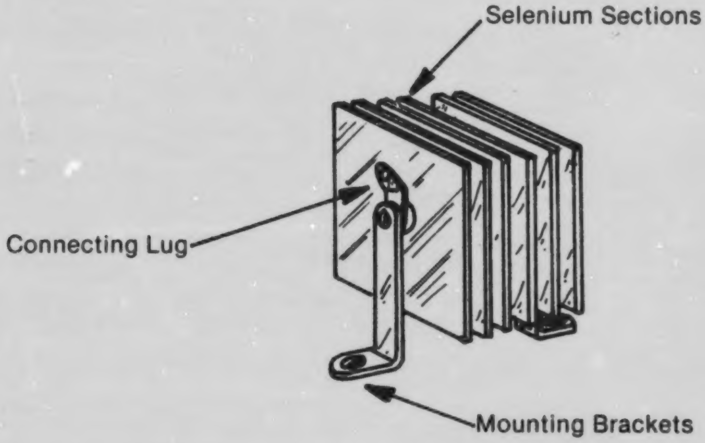
INFORMATION SHEET

IV. Common diode configurations (Figures 10-20)

A. Selenium rectifier

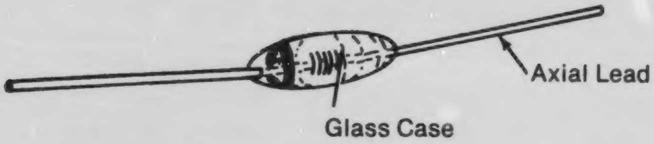
(NOTE: The number of sections in the rectifier may vary depending upon the application. The space between sections allows the device to dissipate heat.)

FIGURE 10


Selenium Sections
Connecting Lug
Mounting Brackets

B. Axial-lead diodes

FIGURE 11


Axial Lead
Glass Case

INFORMATION SHEET

FIGURE 12

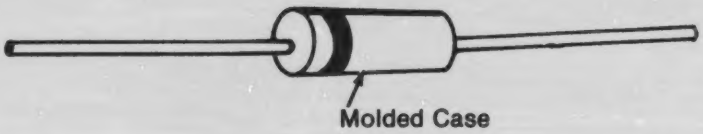

Molded Case

FIGURE 13

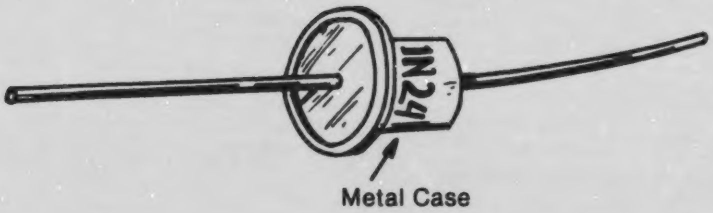

1N24
Metal Case

FIGURE 14

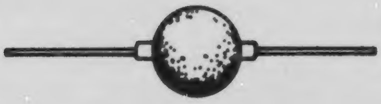
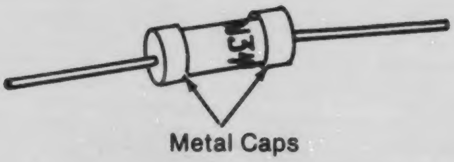


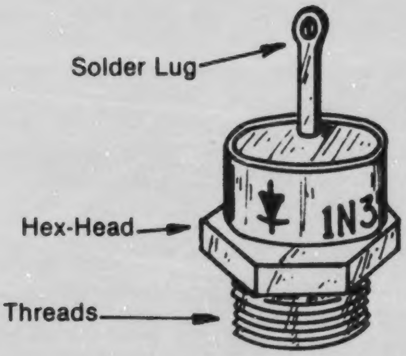
FIGURE 15


N34
Metal Caps

INFORMATION SHEET

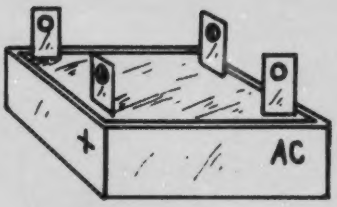
C. Stud-mounted diode

FIGURE 16


Solder Lug
1N3
Hex-Head
Threads

D. Full-wave bridge module

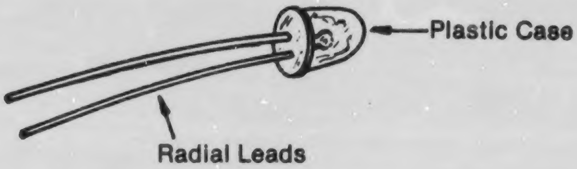
FIGURE 17



E. Light-emitting diode

(NOTE: The color of a light-emitting diode is determined by materials used in its manufacture.)

FIGURE 18

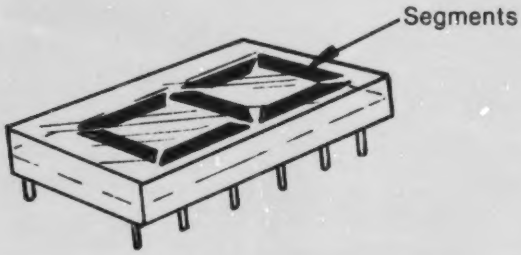

Plastic Case
Radial Leads

INFORMATION SHEET

F. LED display

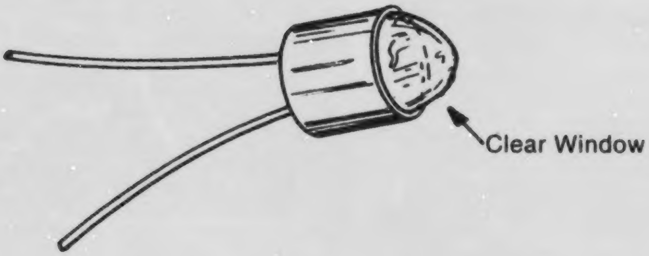
(NOTE: A light-emitting display is composed of many LED segments.)

FIGURE 19



G. Photodiode

FIGURE 20



V. Characteristics of diode materials

A. Silicon — Capable of operating at high temperatures

B. Germanium — Costly; sensitive to small-signal detection; apt to be destroyed by excessive current flow and heat

C. Selenium — Used in specific installations for high-voltage rectifiers

VI. Types of diodes and their uses

A. General-purpose diode — Rectifying alternating current to direct current; switching circuits

INFORMATION SHEET

B. Zener diode — Referencing voltages; regulating voltages

C. Photodiode — Detecting light and measuring intensity

D. Light-emitting diode — Lighting indicators and displays

E. Varactor diode — Oscillating high frequencies

F. Thyrector diode — Protecting circuit from high-voltage transients

G. Diac — Controlling and oscillating alternating-current circuits

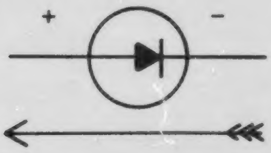
H. Temperature-compensating diode — Stabilizing against temperature drift in oscillator and amplifier circuits

I. Selenium rectifier — Rectifying high-voltage circuits

VII. Forward- and reverse-biased polarities (Figures 21-24)

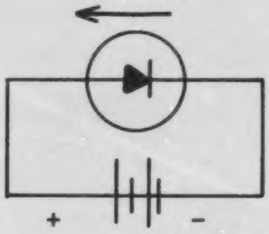
A. Forward biased

FIGURE 21



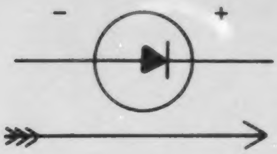
Direction of Electron Flow

FIGURE 22



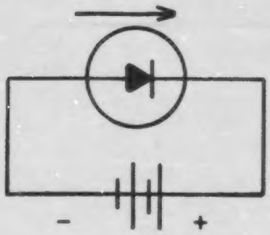
B. Reverse biased

FIGURE 23



Direction of Electron Flow

FIGURE 24



INFORMATION SHEET

VIII. Parts of a semiconductor diode and their functions (Transparency #1)

A. Encapsulating material — Secures small elements, insulates, and provides heat dissipation

B. Anode lead — Connects to positive voltage when diode is forward biased; passes current out of device in forward-biased mode

C. Cathode lead — Connects to negative voltage when diode is forward biased; supplies current flow into device in forward-biased mode

D. p-material — Acts as anode of device; holes account for most of the current flow

E. n-material — Acts as cathode of device; electrons account for most of the current flow

F. pn junction — Provides an area for current flow between p-material and n-material

G. Holes — Act as majority carriers of p-material

H. Excess electrons — Act as majority carriers of n-material

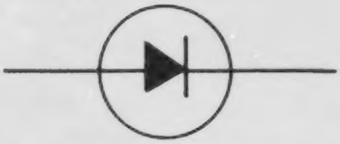
I. Depletion region — Provides area where electrons combine with holes to satisfy molecular-bond requirements; results in an electronic charge and creates the potential barrier

IX. Anode and cathode terminals on diodes and symbols (Assignment Sheet #2)

(NOTE: Drawings are shown with the anodes on the left and cathodes on the right. Other configurations of diodes are common. A technician should consult a reference manual or check the diode with an ohmmeter to determine proper terminals.)

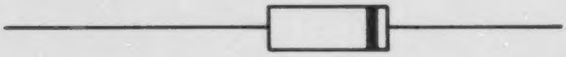
A. Circuit symbol (Figure 25)

FIGURE 25



B. Axial-lead diodes (Figures 26-30)

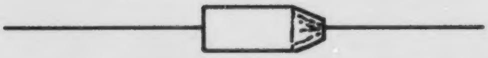
FIGURE 26



(NOTE: The band around the diode corresponds to the line on the circuit symbol.)

INFORMATION SHEET

FIGURE 27



(NOTE: The tapered end on the diode corresponds to the arrowhead of the circuit symbol. This style of diode can be easily confused with capacitors of similar design.)

FIGURE 28

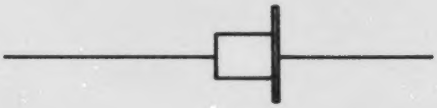
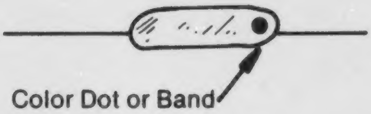
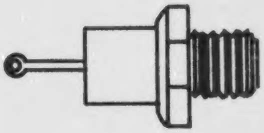


FIGURE 29



C. Stud-mounted diode (Figure 30)

FIGURE 30



X. Biasing effects on the pn junction (Transparency #2)

A. Forward bias — Depletion region is narrowed, thus decreasing the potential barrier and allowing current to flow across the device

B. Reverse bias — Depletion region is widened, thus increasing the potential barrier and restricting current flow across the device

INFORMATION SHEET

XI. Reasons for diode failure (Assignment Sheet #1)

(NOTE: The reasons for diode failure listed here are given in the approximate order of frequency of occurrence, beginning with the most common reason.)

A. Heat

EXAMPLES: Failing to use heat sink when soldering or unsoldering leads; restricted air flow in equipment cabinets due to clogged air screens or defective cooling fans; using too large soldering iron when installing or removing diodes

(NOTE: Stud-mounted diodes are often supplied with an insulating washer to be used when it is necessary to electrically insulate them from the chassis. This washer also restricts heat transfer and should not be used unless it is necessary. Silicon grease aids in heat transfer whether the insulating washer is used or not. Silicon grease also prevents corrosion and ensures electrical contact.)

B. Shock/stress

EXAMPLES: Dropping components onto hard surfaces; cutting component leads with cutters that cause a sharp snap of the leads; jarring printed circuit boards; using excessive pressure on stud-mounted diodes; contraction and expansion due to temperature extremes, particularly where axial-lead diodes are installed with the leads directly between terminal points with no bends; flexing or bending of printed circuit boards

C. Excessive current

EXAMPLES: Short circuits; other component failures; improper adjustment of equipment; improper substitution of components

D. Excessive reverse voltage

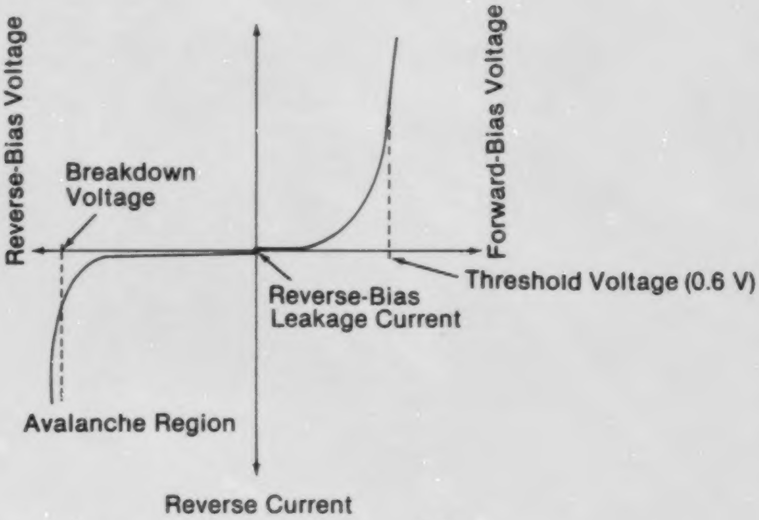
EXAMPLES: High-voltage spikes created by lightning; surges in the power distribution system; poor electrical connections; installation in reverse

INFORMATION SHEET

XII. Parts of diode characteristic curves

A. Silicon diode (Figure 31; Transparency #3)

FIGURE 31



1. Threshold voltage

   (NOTE: This is the voltage at which the diode begins significant conduction due to majority carriers. For silicon, the threshold voltage is about 0.6 volts.)

2. Reverse-bias leakage current

3. Breakdown voltage

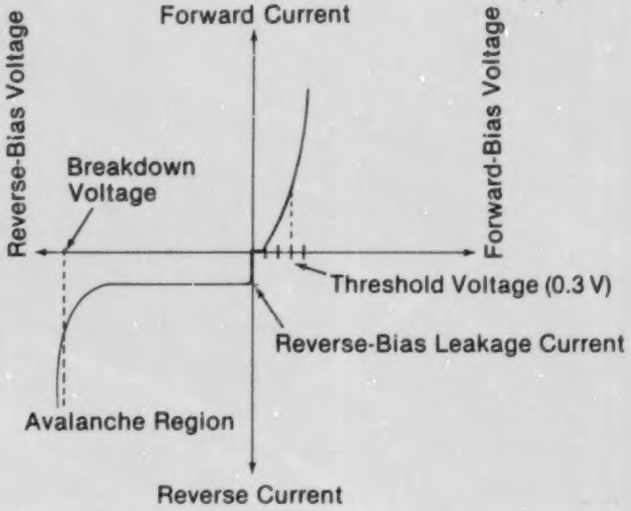
4. Avalanche region

   (NOTE: Ordinary diodes are destroyed by excessive reverse current after breakdown voltage is applied.)

INFORMATION SHEET

B. Germanium diode (Figure 32; Transparency #4)

FIGURE 32


Forward Current
Reverse-Bias Voltage
Forward-Bias Voltage
Breakdown Voltage
Threshold Voltage (0.3 V)
Reverse-Bias Leakage Current
Avalanche Region
Reverse Current

1. Threshold voltage

   (NOTE: Threshold voltage is about 0.3 volts for germanium material.)

2. Reverse-bias leakage current

   (NOTE: Reverse-bias leakage current is significantly greater than the silicon material characteristic.)

3. Breakdown voltage

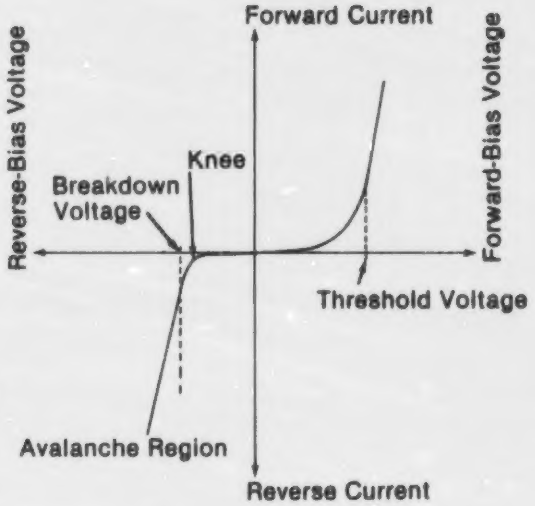
4. Avalanche region

   (NOTE: Germanium diodes are more easily destroyed than silicon diodes.)

INFORMATION SHEET

C. Zener diode (Figure 33; Transparency #5)

FIGURE 33


Forward Current
Reverse-Bias Voltage
Forward-Bias Voltage
Knee
Breakdown Voltage
Threshold Voltage
Avalanche Region
Reverse Current

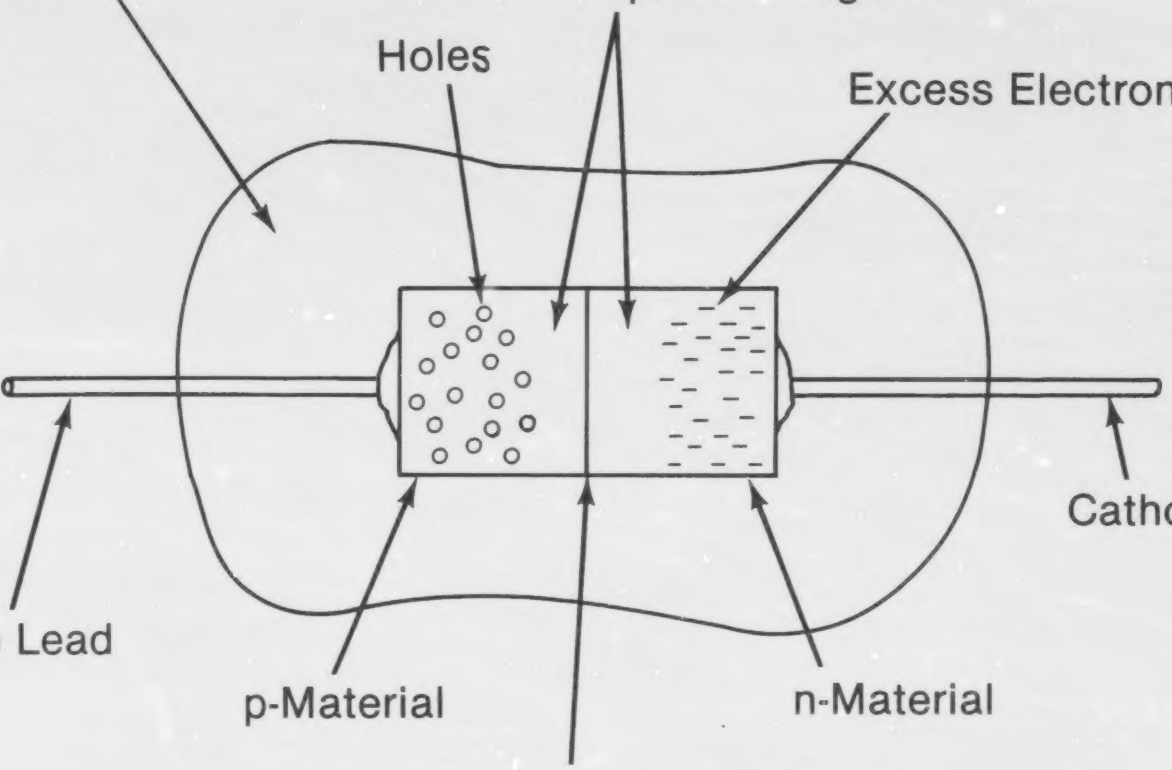
1. Threshold voltage
2. Knee

   (NOTE: Zener diodes are designed for a sharp curve at the knee.)

3. Breakdown voltage
4. Avalanche region

   (NOTE: Zener diodes are designed to operate in the avalanche region, without destruction to certain limits. Zener diodes are more heavily doped than ordinary diodes.)

Parts of a Semiconductor Diode



Encapsulating Material

Depletion Region

Holes

Excess Electrons

Cathode Lead

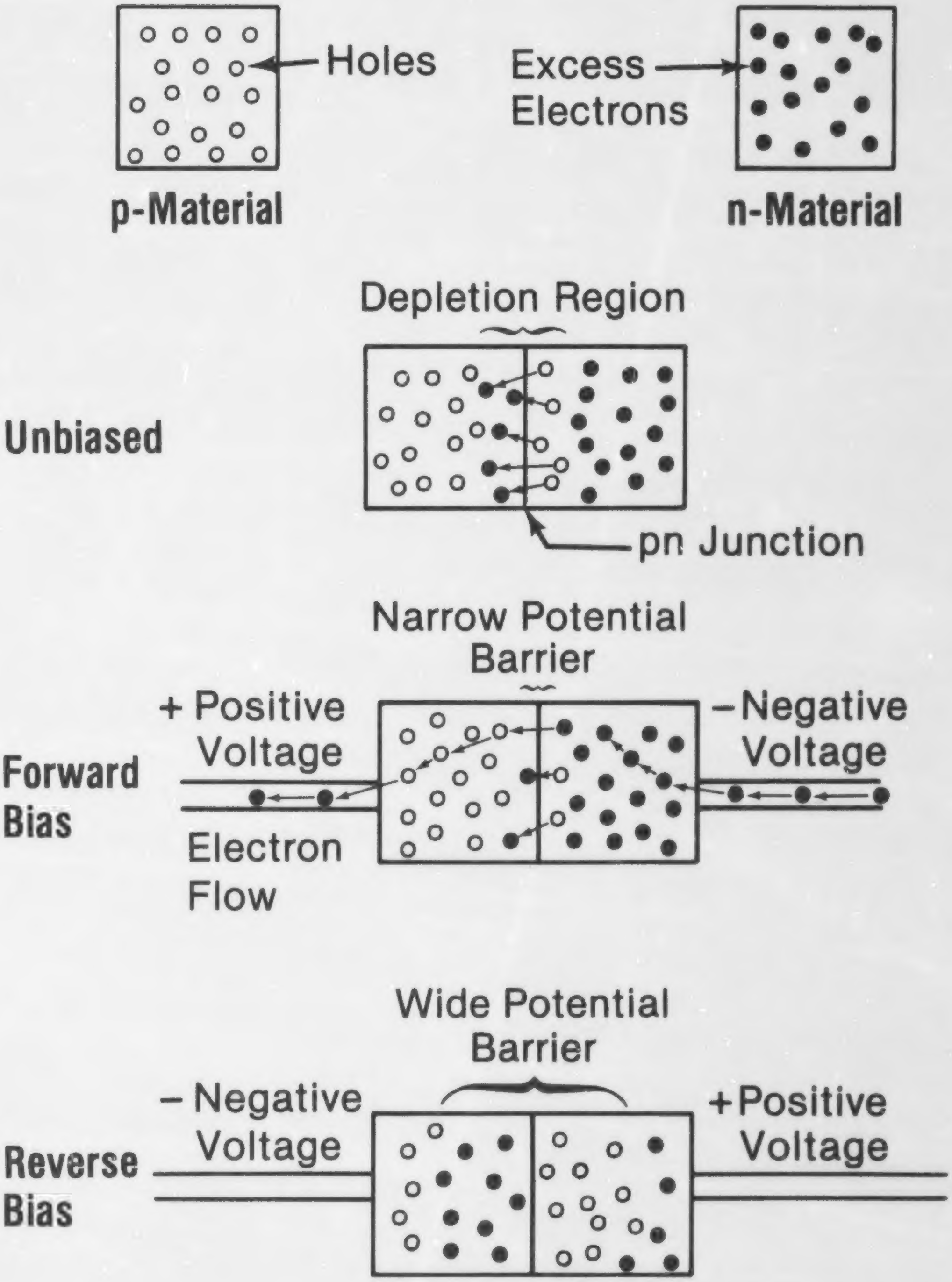
Anode Lead

p-Material

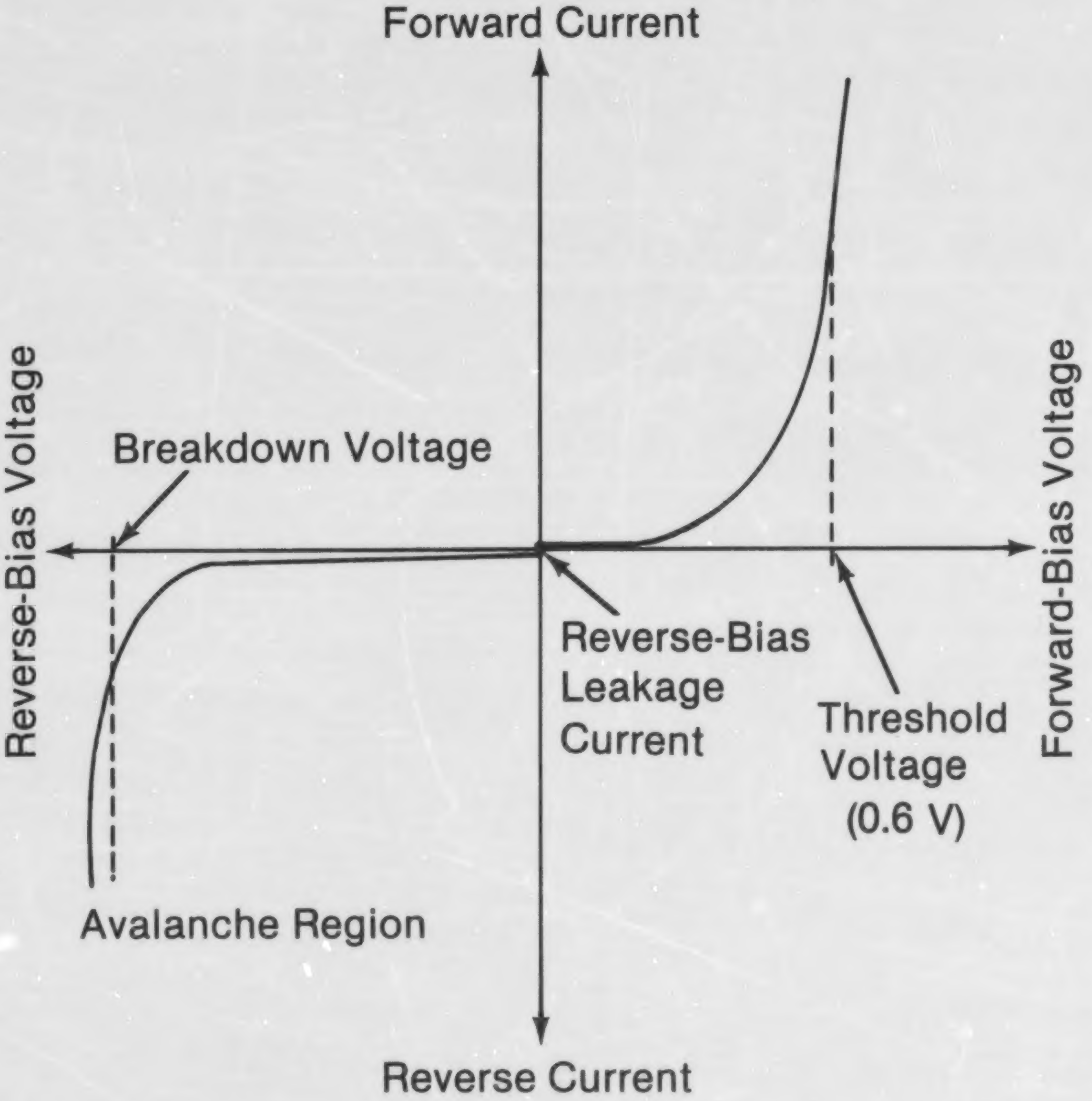
n-Material

pn Junction

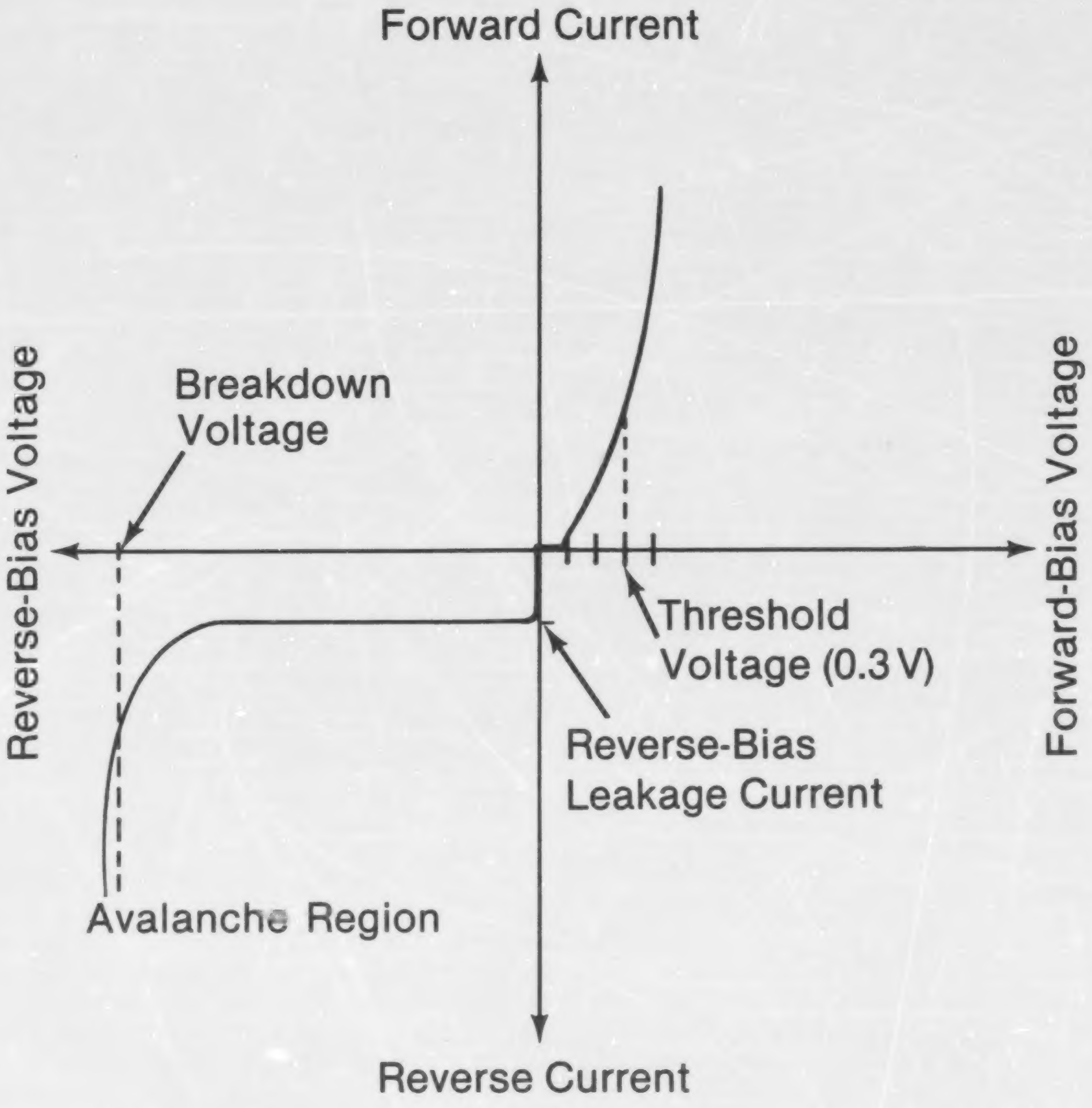
Biasing Effects on the pn Junction


Holes
Excess Electrons
p-Material
n-Material
Depletion Region
Unbiased
pn Junction
Narrow Potential Barrier
+ Positive Voltage
– Negative Voltage
Forward Bias
Electron Flow
Wide Potential Barrier
– Negative Voltage
+ Positive Voltage
Reverse Bias

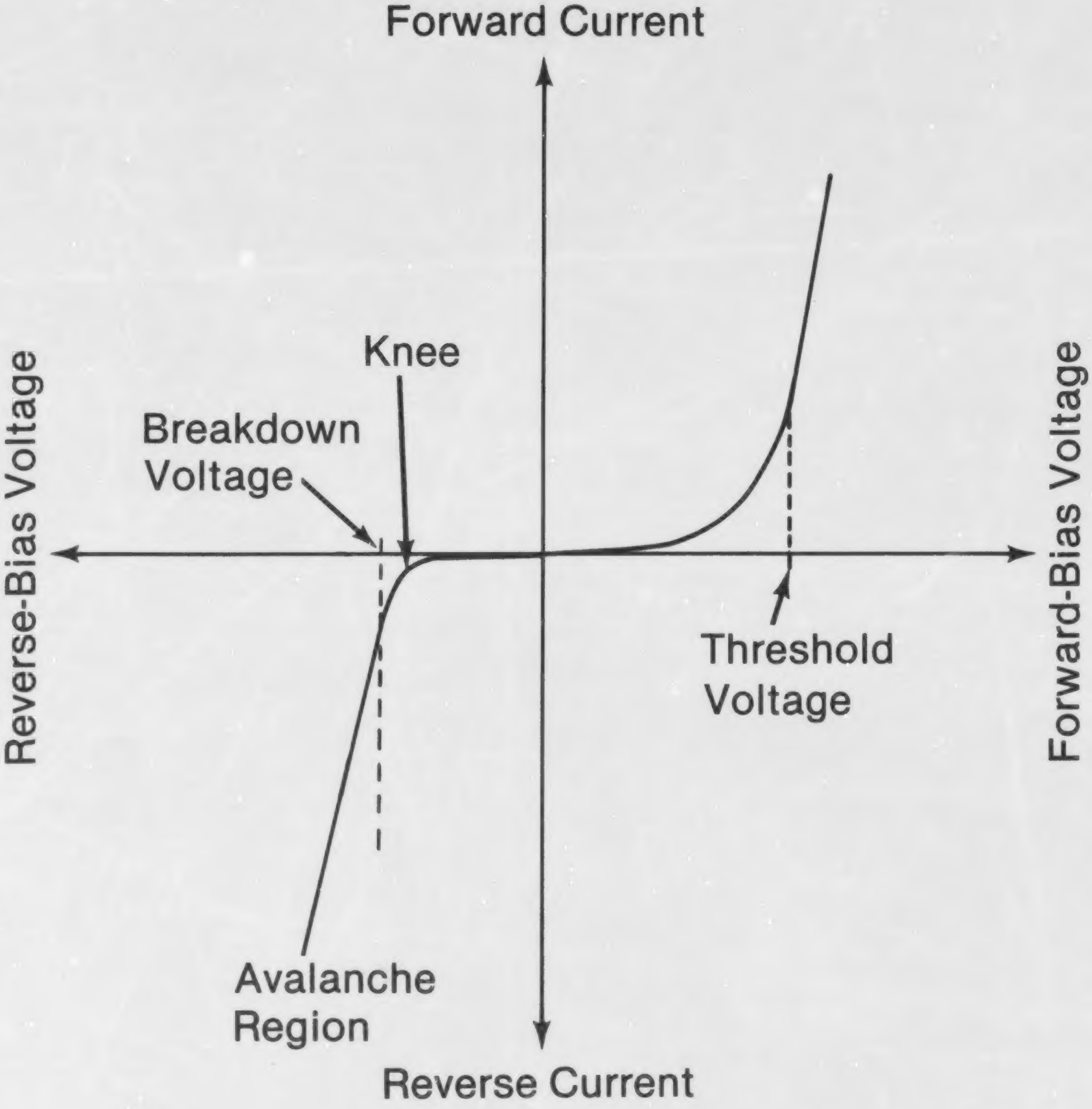
Silicon-Diode Characteristic Curve



Germanium-Diode Characteristic Curve


Forward Current
Breakdown Voltage
Reverse-Bias Voltage
Forward-Bias Voltage
Threshold Voltage (0.3 V)
Reverse-Bias Leakage Current
Avalanche Region
Reverse Current

Zener-Diode Characteristic Curve



SOLID-STATE DIODES
UNIT II

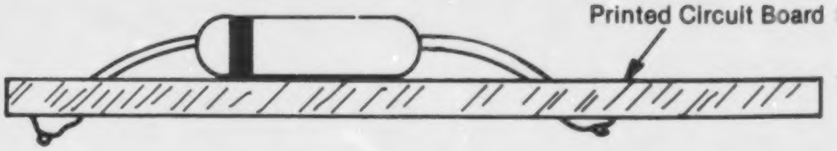
ASSIGNMENT SHEET #1 — IDENTIFY PROPER AND IMPROPER DIODE INSTALLATION TECHNIQUES

NAME ______________________________ SCORE ______________

Some semiconductor diodes are so sensitive that an ohmmeter can destroy them. All semiconductor diodes should be handled with care.

Study the handling methods depicted in the following illustrations. Check "proper" or "improper" for each illustration, and then explain your answer in the space provided. After you have finished, submit your work to the instructor for evaluation.

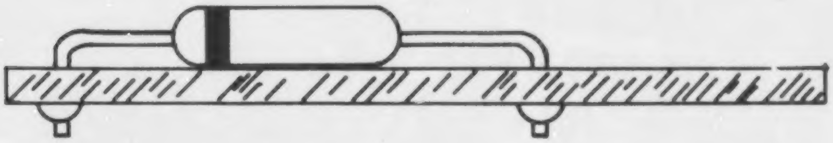
A. _____Proper _____Improper



Reason: ____

____

B. _____Proper _____Improper

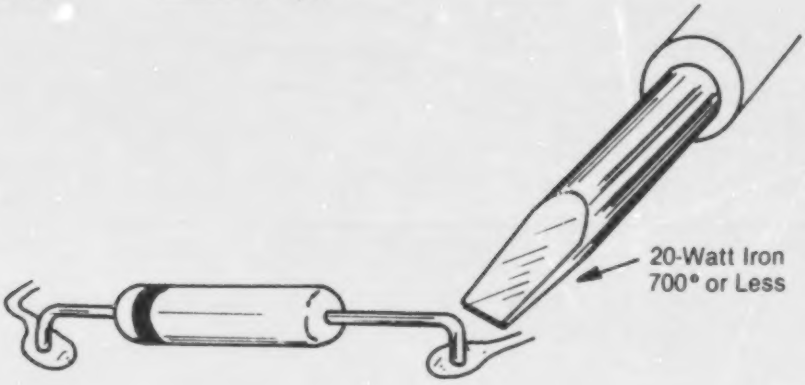


Reason: ____

____

ASSIGNMENT SHEET #1

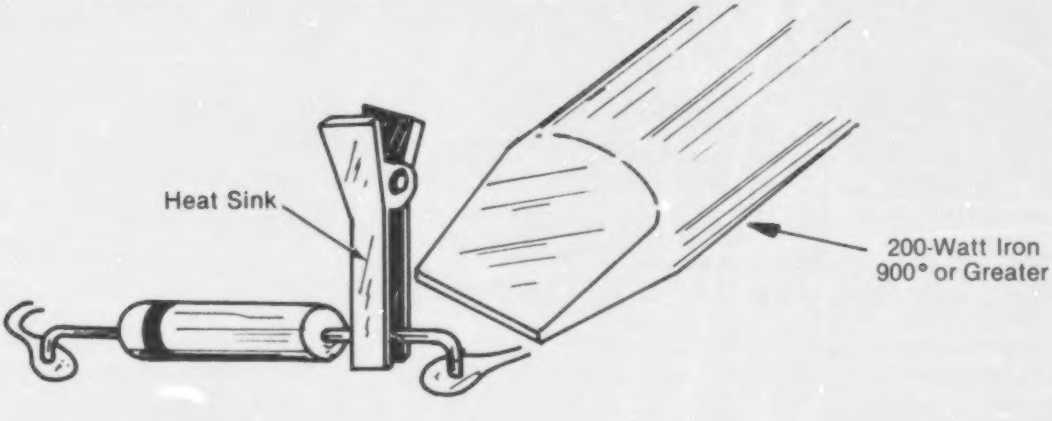
C. _____Proper _____Improper


20-Watt Iron
700° or Less

Reason: ____

____

D. _____Proper _____Improper

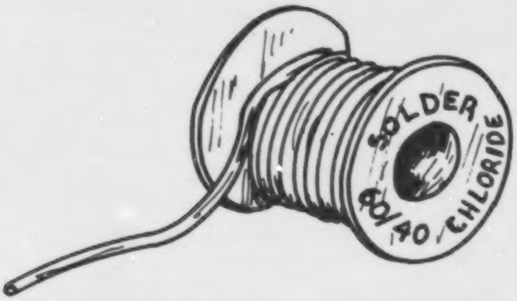

Heat Sink
200-Watt Iron
900° or Greater

Reason: ____

____

ASSIGNMENT SHEET #1

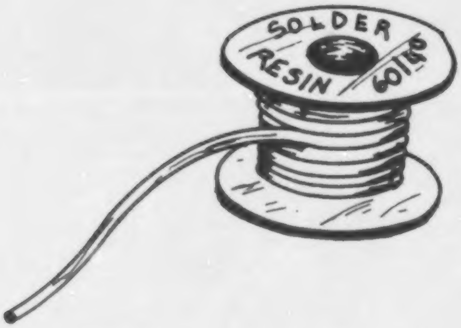
E. _____Proper _____Improper


SOLDER
60/40
CHLORIDE

Reason: ______________________________

____

F. _____Proper _____Improper


SOLDER
RESIN
60/40

Reason: ______________________________

____

SOLID-STATE DIODES
UNIT II

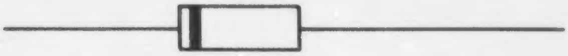
ASSIGNMENT SHEET #2 — DETERMINE THE CATHODE TERMINAL OF DIODES AND SYMBOLS

NAME ______________________________ SCORE ______________

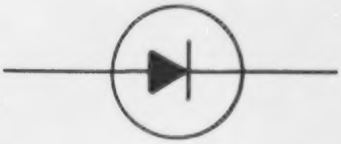
A technician must be able to determine which end of a diode or symbol represents the cathode end.

Study the following illustrations. Write "C" at the end that is the cathode end. Submit your work to the instructor for evaluation when you have finished.

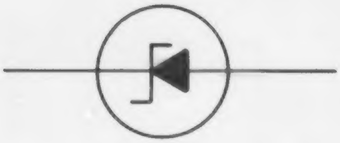
A.



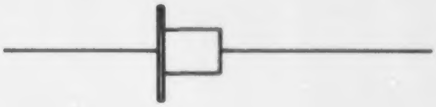
B.



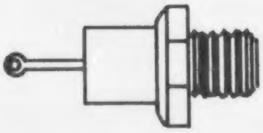
C.



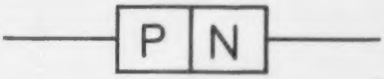
D.



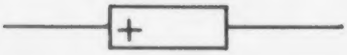
E.



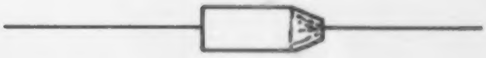
F.



G.



H.



SOLID-STATE DIODES
UNIT II

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

A. Improper — Leads stretched tight

B. Proper — Leads bent

C. Improper — No heat sink

D. Improper — Soldering iron too large

E. Improper — Chloride-core solder is not used on electronic components

F. Proper — 60/40 resin solder is normally used on electronic components

Assignment Sheet #2

A. Cathode is on left

B. Cathode is on right

C. Cathode is on left

D. Cathode is on left

E. Cathode is on right

F. Cathode is on right

G. Cathode is on right

H. Cathode is on right

SOLID-STATE DIODES
UNIT II

JOB SHEET #1 — CONSTRUCT A DIODE CIRCUIT FOR OBSERVING THE EFFECTS OF DIRECT CURRENT ON A SEMICONDUCTOR DIODE

I. Equipment and materials

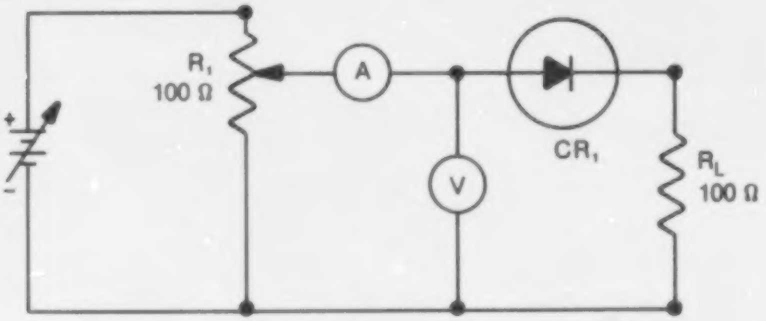
- A. Direct-current power supply capable of an output of 0 to 5 volts
- B. Variable resistor, 100 ohm
- C. Resistor, 100 ohm, ½ watt
- D. Two multimeters
- E. Sheet of graph paper
- F. Diode, 1N4001 or one of equivalent or higher rating
- G. Soldering iron
- H. Breadboard

II. Procedure

A. Construct circuit as shown in Figure 34

(NOTE: Be sure that potentiometer is adjusted to maximum resistance, maximum indication on voltmeter. Have instructor check circuit.)

FIGURE 34



B. Vary voltage in steps of 0.1 volts; record readings up to 1.5 volts on graph

(NOTE: Use the *y* coordinate for current and the *x* coordinate for voltage.)

C. Adjust potentiometer to minimum voltage indication on meter

D. Reverse connections of diode

SOLID-STATE DIODES
UNIT II

JOB SHEET #2 — CONSTRUCT A DIODE CIRCUIT FOR OBSERVING THE EFFECTS OF ALTERNATING CURRENT ON A SEMICONDUCTOR DIODE

I. Equipment and materials

A. Alternating-current power supply capable of 6.3-0-6.3 VAC, or transformer with 6.3-VAC center-tap output

B. Two diodes, 1N4001 or equivalent

C. Oscilloscope

D. Load resistor, 390-ohm, ½ watt

E. Multimeter

F. Breadboard

II. Procedure

A. Construct one of the following circuits as designated by instructor (Figures 35 and 36)

(NOTE: Have instructor check circuit.)

FIGURE 35

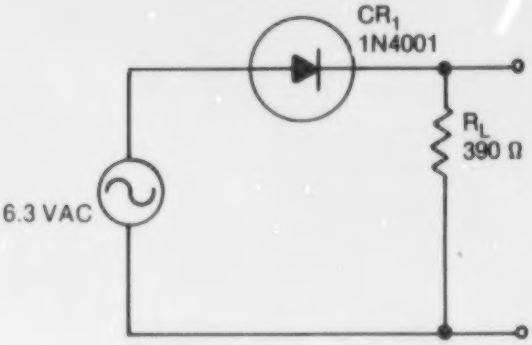
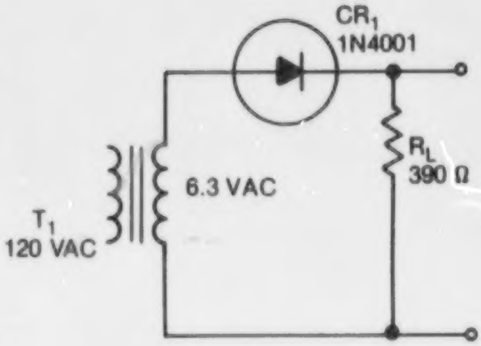


FIGURE 36



JOB SHEET #2

B. Observe signal across resistor with oscilloscope; record peak value, and sketch several pulses of this output in the space below

Peak value = ____________________

C. Measure peak-to-peak voltage of input waveform; record

Pk-pk voltage = ____________________

D. Measure voltage across load resistor with multimeter

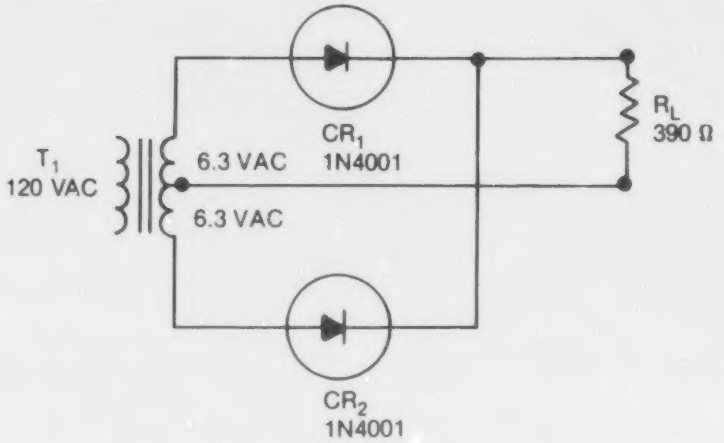
(NOTE: Record voltage on waveform.)

E. Compare multimeter reading across resistor with peak voltage measured on oscilloscope

F. Construct circuit as shown in Figure 37

(NOTE: Have instructor check circuit.)

FIGURE 37



JOB SHEET #2

G. Repeat steps B through E

(NOTE: Discuss your results with the instructor.)

Peak value = ______________________

Pk-pk voltage = ______________________

H. Disconnect oscilloscope and multimeter; put away equipment and materials

SOLID-STATE DIODES
UNIT II

JOB SHEET #3 — USE AN OHMMETER TO DETERMINE THE ANODE AND CATHODE OF DIODES

I. Equipment and materials

A. Ohmmeter with test leads

B. Several diodes, taped to cover any indication of which end is the cathode or anode

(NOTE: Diodes will be furnished by instructor.)

II. Procedure

A. Set meter controls to measure ohms

B. Connect the leads across each diode, first in one direciton, and then in the other

(NOTE: Recall that the cathode accepts electron flow, and in the forward-biased direction, the cathode connects to the negative. Use this characteristic to determine which ends of the components are the cathodes.)

C. Align diodes on workbench with cathodes all pointing away from you

(NOTE: Discuss your results with your instructor.)

D. Disconnect ohmmeter; put away equipment and materials

SOLID-STATE DIODES
UNIT II

JOB SHEET #4 — USE AN OHMMETER TO TEST FOR DEFECTIVE DIODES

I. Equipment and materials

A. Ohmmeter with test leads

B. Assortment of diodes furnished by instructor

II. Procedure

(NOTE: Recall that diodes pass current easily in one direction but not in the opposite direction. Use this information to determine which diodes may be defective.)

A. Connect ohmmeter across diodes, one at a time, and switch leads to determine whether there is a difference in conductivity

B. Separate diodes by placing defective ones on workbench in a group to the left

(NOTE: Discuss your results with your instructor.)

C. Disconnect ohmmeter; put away equipment and materials

SOLID-STATE DIODES
UNIT II

JOB SHEET #5 — USE A SEMICONDUCTOR TESTER TO TEST FOR DEFECTIVE DIODES

I. Equipment and materials

- A. Semiconductor tester with test leads or diode clips
- B. Instruction booklet for semiconductor tester
- C. Assortment of diodes furnished by instructor

II. Procedure

- A. Read instruction-booklet procedure for testing diodes
- B. Test each diode carefully according to the procedure for tester being used; record each measurement indication on data sheet on the following page
- C. Determine whether or not the diodes are defective; record this on data sheet
- D. Record diode number on data sheet on the following page

  (NOTE: Discuss your results with the instructor.)
- E. Disconnect tester; put away equipment and materials

JOB SHEET #5

Data Sheet

Student name ______________________________

Diode number or type					
First reading description					
Value read					
Second reading description					
Value read					
Other reading, if any					
Other reading, if any					
Determination (good or bad)					

SOLID-STATE DIODES
UNIT II

TEST

NAME ______________________________ SCORE ______________

1. Match terms associated with solid-state diodes to their correct definitions. Write the correct numbers in the blanks. Terms and definitions continue on the next page.

______a. Area where p- and n-type semiconductor materials interface

______b. Two-terminal (anode and cathode) device that exhibits easy movement of electrons from cathode to anode when proper voltage is applied but resists movement of electrons from anode to cathode

______c. Tendency of a circuit to change characteristics as its temperature changes

______d. Voltage spikes resulting from interferences in power distribution

______e. Conversion of alternating current to direct current

______f. Semiconductor material with too few outer-shell electrons to meet molecular-bond requirements

______g. Resistance to current flow at the pn junction of semiconductor materials; results from electrons and holes combining to form a neutral zone

______h. Semiconductor material with more outer-shell electrons than required by the bond

______i. Adding impurities to a pure semiconductor material

______j. Extra electron in bonding structure of a semiconductor material; electron is free to move

1. Diode
2. pn junction
3. Excess electron
4. Doping
5. High-voltage transients
6. Rectification
7. Temperature drift
8. p-material
9. Potential barrier
10. n-material

TEST

______k. Chart showing effects of forward and reverse biasing of a semiconductor diode

______l. Temperature of air or liquid surrounding an electrical device

______m. Point beyond which an increase in voltage produces no additional increase in current flow

______n. Point in the semiconductor diode at which forward-bias voltage overcomes potential barrier for sharp current increase

______o. Point in the semiconductor diode at which reverse bias breaks down the semiconductor device

11. Saturation point
12. Ambient temperature
13. Threshold voltage
14. Characteristic curve
15. Breakdown voltage

2. Match abbreviations associated with solid-state diodes to their correct interpretations. Write the correct numbers in the blanks.

______a. Crystal rectifier

______b. Light-emitting diode

______c. Liquid-crystal display

______d. Silicon

______e. Greek letter lambda; signifies light

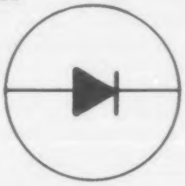
______f. Germanium

1. CR
2. LED
3. Si
4. λ
5. Ge
6. LCD

3. Identify solid-state diode symbols. Write the correct names in the blanks.

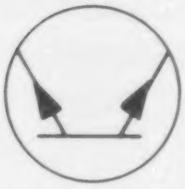
General-purpose diode
Light-emitting diode (LED)
Varactor diode (varicap diode)
Zener diode
Temperature-compensating diode

Thyrector diode
Diac
Photodiode
Full-wave diode-bridge rectifier

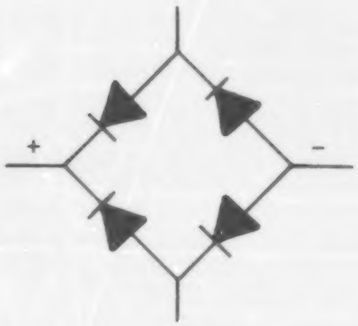


a. ______________________________

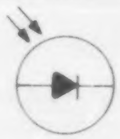
TEST



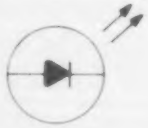
b. ____



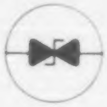
c. ____



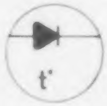
d. ____



e. ____

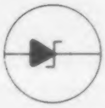


f. ____

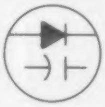


g. ____

TEST



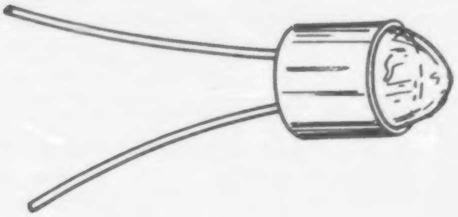
h. ____



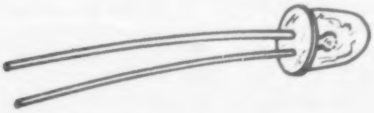
i. ____

4. Identify common diode configurations. Write the correct names in the blanks. A name may be used more than once.

Selenium rectifier
Axial-lead diode
Stud-mounted diode
Full-wave bridge module
Light-emitting diode
LED display
Photodiode

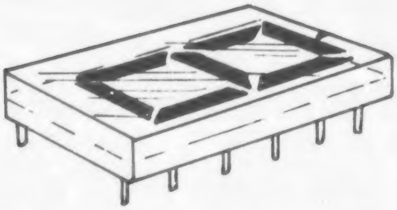


a. ____

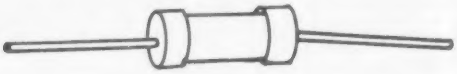


b. ____

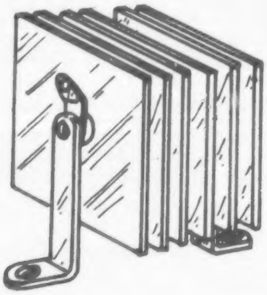
TEST



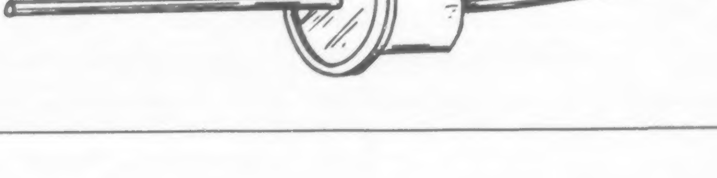
c. ______________________________



d. ______________________________

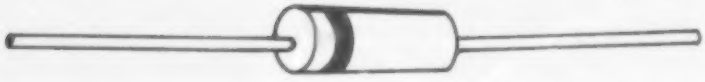


e. ______________________________

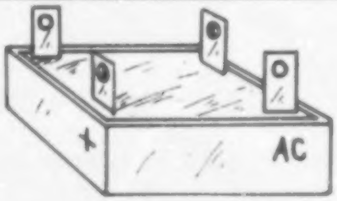


f. ______________________________

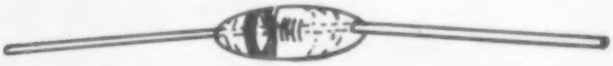
TEST



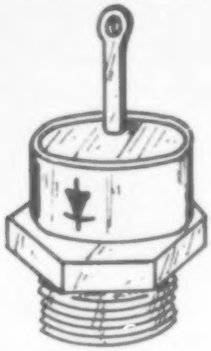
g. ______________________________



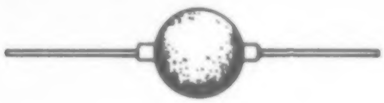
h. ______________________________



i. ______________________________



j. ______________________________



k. ______________________________

TEST

5. Match diode materials to their correct characteristics. Write the correct numbers in the blanks.

______a. Used in specific installations for high-voltage rectifiers

______b. Capable of operating at high temperatures

______c. Costly; sensitive to small-signal detection; apt to be destroyed by excessive current flow and heat

1. Silicon
2. Germanium
3. Selenium

6. Match types of diodes to their correct uses. Write the correct numbers in the blanks.

______a. Stabilizing against temperature drift in oscillator and amplifier circuits

______b. Controlling and oscillating alternating-current circuits

______c. Rectifying alternating current to direct current; switching circuits

______d. Protecting circuit from high-voltage transients

______e. Oscillating high frequencies

______f. Detecting light and measuring intensity

______g. Referencing voltages; regulating voltages

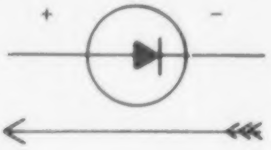
______h. Lighting indicators and displays

______i. Rectifying high-voltage circuits

1. General-purpose diode
2. Zener diode
3. Photodiode
4. Light-emitting diode
5. Varactor diode
6. Thyrector diode
7. Diac
8. Temperature-compensating diode
9. Selenium rectifier

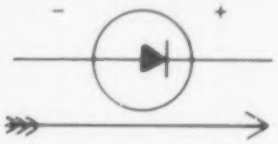
TEST

7. Distinguish between forward- and reverse-biased polarities. Write the correct names in the blanks.



Direction of Electron Flow

a. ______________________________



Direction of Electron Flow

b. ______________________________

8. Match parts of a semiconductor diode to their correct functions. Write the correct numbers in the blanks.

_____a. Provides an area for current flow between p-material and n-material

_____b. Act as majority carriers of p-material

_____c. Secures small elements, insulates, and provides heat dissipation

_____d. Acts as cathode of device; electrons account for most of the current flow

_____e. Connects to positive voltage when diode is forward biased; passes current out of device in forward-biased mode

_____f. Provides area where electrons combine with holes to satisfy molecular-bond requirements; results in an electronic charge and creates the potential barrier

_____g. Connects to negative voltage when diode is forward biased; supplies current flow into device in forward-biased mode

_____h. Act as majority carriers of n-material

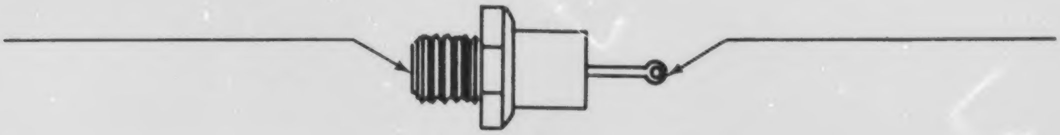
_____i. Acts as anode of device; holes account for most of the current flow

1. Encapsulating material
2. Anode lead
3. Cathode lead
4. p-material
5. n-material
6. pn junction
7. Holes
8. Excess electrons
9. Depletion region

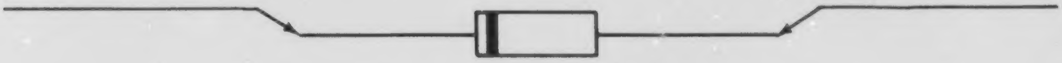
TEST

9. Label anode and cathode terminals on diodes and symbols in the following drawings.

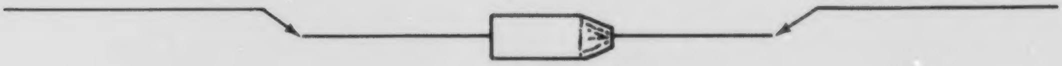
a. Stud-mounted diode



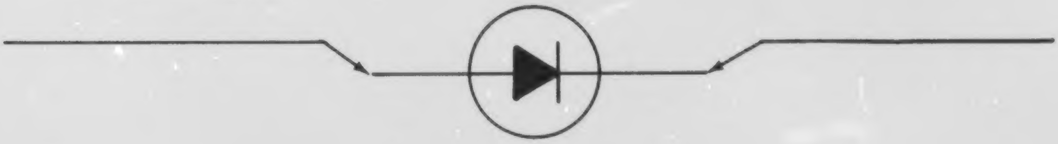
b. Axial-lead diode



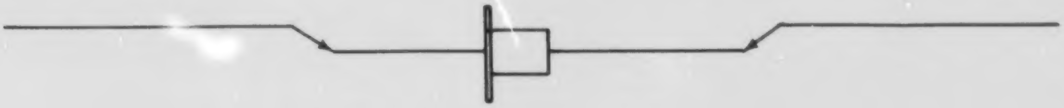
c. Axial-lead diode



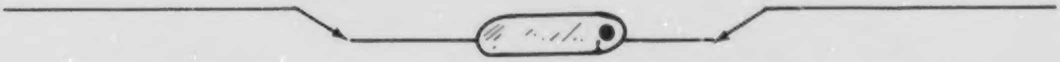
d. Circuit symbol



e. Axial-lead diode



f. Axial-lead diode



TEST

10. Describe biasing effects on the pn junction.

a. Forward bias — ______________________________

____

____

b. Reverse bias — ______________________________

____

____

11. Name reasons for diode failure.

a. ______________________________

b. ______________________________

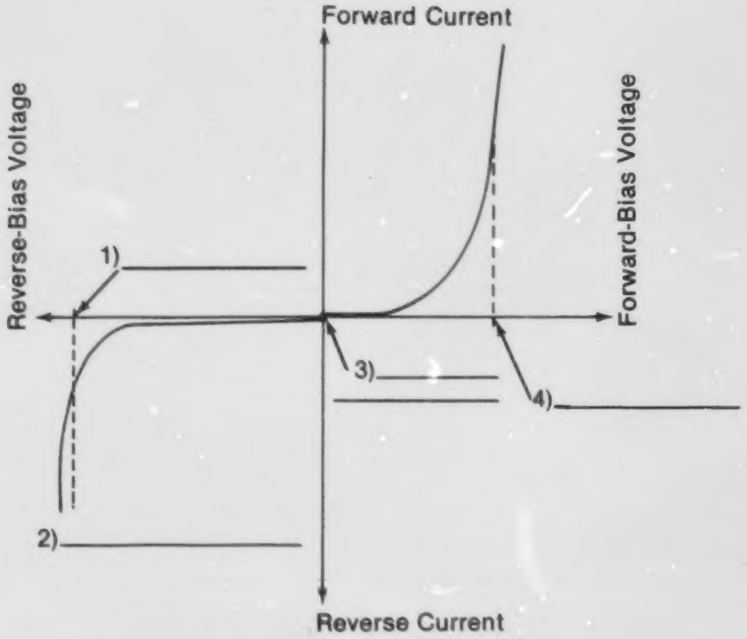
c. ______________________________

d. ______________________________

12. Identify parts of the following diode characteristic curves. Write the correct names in the spaces provided. A name may be used more than once.

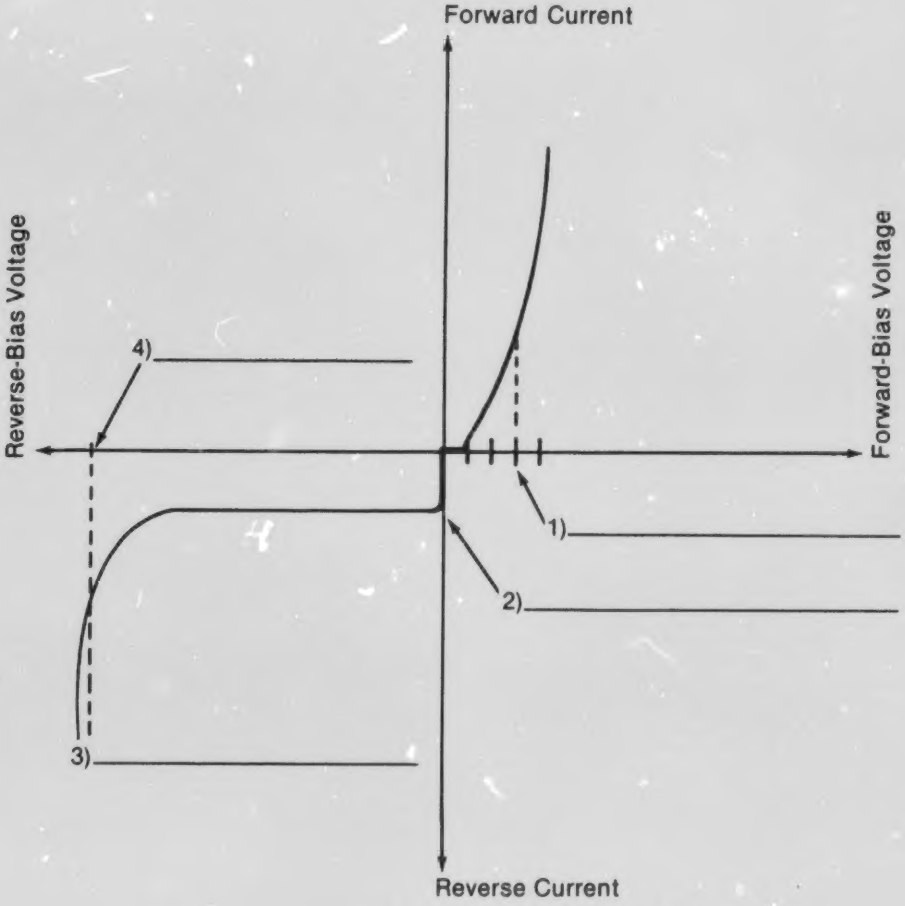
Threshold voltage
Breakdown voltage
Reverse-bias leakage current
Avalanche region
Knee

a. Silicon-diode characteristic curve


Forward Current
Reverse-Bias Voltage
Forward-Bias Voltage
1) ______________
2) ______________
3) ______________
____
4) ______________
Reverse Current

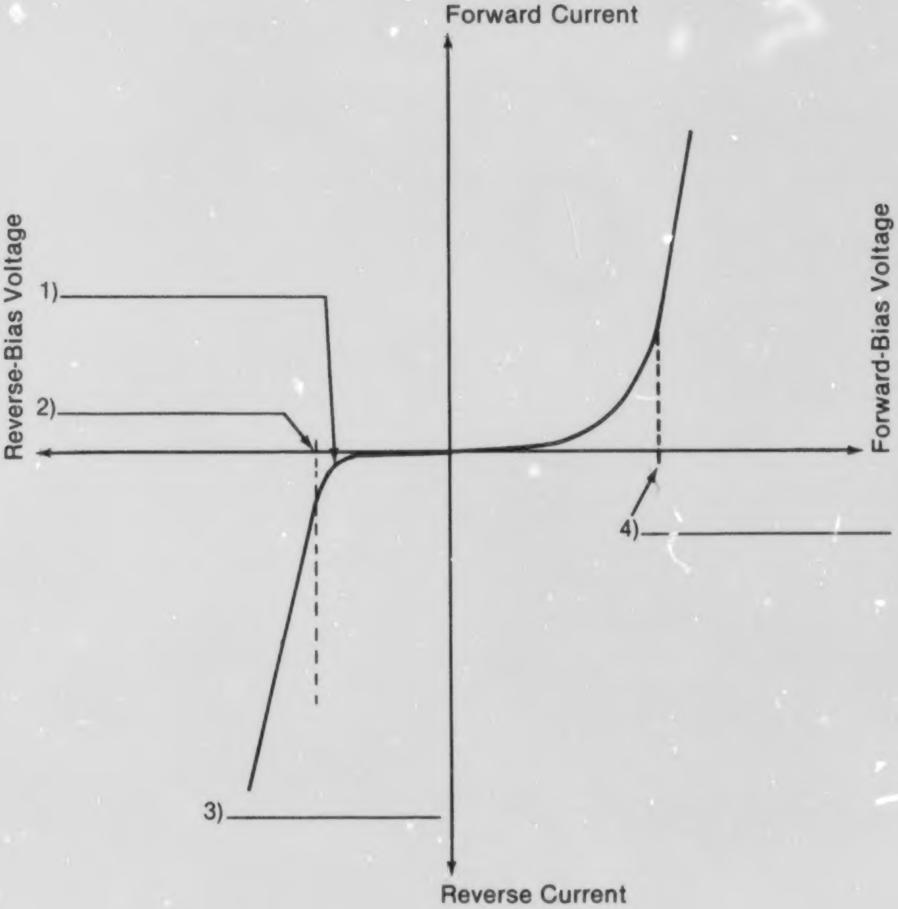
TEST

b. Germanium-diode characteristic curve


Forward Current
Reverse-Bias Voltage
Forward-Bias Voltage
Reverse Current
1) ____________
2) ____________
3) ____________
4) ____________

TEST

c. Zener-diode characteristic curve


Forward Current
Reverse-Bias Voltage
Forward-Bias Voltage
1)
2)
3)
4)
Reverse Current

TEST

(NOTE: Test questions 13 and 14 list the assignment and job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

13. Identify proper and improper diode installation techniques.

14. Demonstrate the ability to:

    a. Construct a diode circuit for observing the effects of direct current on a semiconductor diode.

    b. Construct a diode circuit for observing the effects of alternating current on a semiconductor diode.

    c. Use an ohmmeter to determine the anode and cathode of diodes.

    d. Use an ohmmeter to test for defective diodes.

    e. Use a semiconductor tester to test for defective diodes.

SOLID-STATE DIODES
UNIT II

ANSWERS TO TEST

1.	a.	2	f.	8	k.	14
	b.	1	g.	9	l.	12
	c.	7	h.	10	m.	11
	d.	5	i.	4	n.	13
	e.	6	j.	3	o.	15

2.	a.	1	d.	3
	b.	2	e.	4
	c.	6	f.	5

3.
a. General-purpose diode
b. Diac
c. Full-wave diode-bridge rectifier
d. Photodiode
e. Light-emitting diode (LED)
f. Thyrector diode
g. Temperature-compensating diode
h. Zener diode
i. Varactor diode (varicap diode)

4.	a.	Photodiode	g.	Axial-lead diode
	b.	Light-emitting diode	h.	Full-wave bridge module
	c.	LED display	i.	Axial-lead diode
	d.	Axial-lead diode	j.	Stud-mounted diode
	e.	Selenium rectifier	k.	Axial-lead diode
	f.	Axial-lead diode		

ANSWERS TO TEST

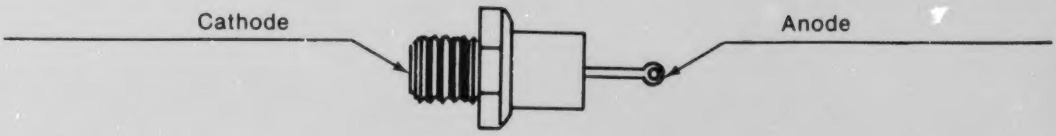
5. a. 3
   b. 1
   c. 2

6. a. 8
   b. 7
   c. 1
   d. 6
   e. 5
   f. 3
   g. 2
   h. 4
   i. 9

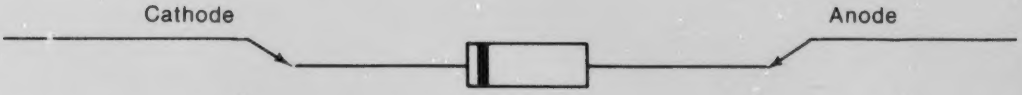
7. a. Forward biased
   b. Reverse biased

8. a. 6
   b. 7
   c. 1
   d. 5
   e. 2
   f. 9
   g. 3
   h. 8
   i. 4

9. a. Stud-mounted diode

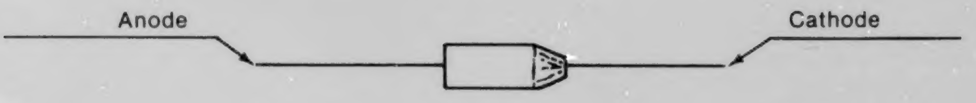

Cathode
Anode

   b. Axial-lead diode

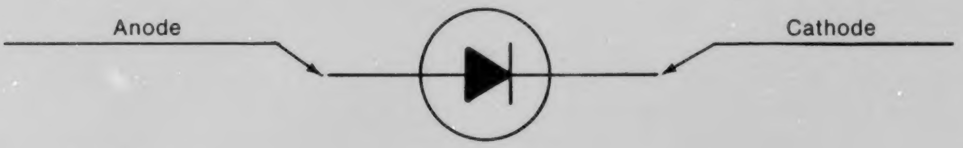

Cathode
Anode

ANSWERS TO TEST

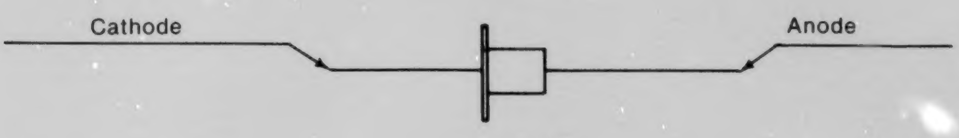
c. Axial-lead diode


Anode
Cathode

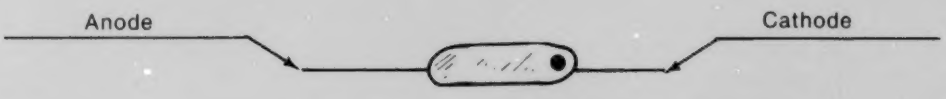
d. Circuit symbol


Anode
Cathode

e. Axial-lead diode


Cathode
Anode

f. Axial-lead diode


Anode
Cathode

10. Description should include the following

    a. Forward bias — Depletion region is narrowed, thus decreasing the potential barrier and allowing current to flow across the device

    b. Reverse bias — Depletion region is widened, thus increasing the potential barrier and restricting current flow across the device

11. a. Heat

    b. Shock/stress

    c. Excessive current

    d. Excessive reverse voltage

ANSWERS TO TEST

12. a.
    1) Breakdown voltage
    2) Avalanche region
    3) Reverse-bias leakage current
    4) Threshold voltage (0.6 V)

    b.
    1) Threshold voltage (0.3 V)
    2) Reverse-bias leakage current
    3) Avalanche region
    4) Breakdown voltage

    c.
    1) Knee
    2) Breakdown voltage
    3) Avalanche region
    4) Threshold voltage

13. Evaluated to the satisfaction of the instructor

14. Performance skills evaluated to the satisfaction of the instructor

BIPOLAR TRANSISTORS
UNIT III

UNIT OBJECTIVE

After completing this unit, the student should be able to calculate transistor gains and ratios, check transistors, and construct circuits to analyze their operation. The student will show this knowledge by completing assignment sheets, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with bipolar transistors to their correct definitions.
2. Match abbreviations associated with bipolar transistors to their correct interpretations.
3. Label transistor circuit symbols.
4. Identify common transistor cases.
5. Identify the emitter, base, and collector of various transistors.
6. Select from a list characteristics of transistor emitters, bases, and collectors.
7. Identify basic transistor circuit configurations.
8. List characteristics of transistor circuit configurations.
9. Indicate the direction of current flow in the external circuits of transistors.
10. List bipolar transistor applications.
11. List bipolar transistor classifications.
12. Calculate transistor voltage, current, and power gain.
13. Calculate alpha and beta values for common-emitter and common-base circuits.
14. Construct a transistor load line.
15. List transistor characteristics indicated by the arrowhead symbol.
16. Demonstrate the ability to
    a. Analyze the common-emitter circuit.

OBJECTIVE SHEET

b. Analyze the common-base circuit

c. Analyze the common-collector circuit.

d. Make various out-of-circuit transistor checks.

e. Use a transistor tester to check transistors.

BIPOLAR TRANSISTORS
UNIT III

SUGGESTED ACTIVITIES

I. Suggested activities

A. Make transparencies.

B. Collect transistors with different cases and of different power ratings to show to students.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information, assignment, and job sheets.

F. Discuss information and assignment sheets.

G. Copy a transistor specification sheet for the students from a manufacturer's reference manual. Discuss the parameters and the specifications. Emphasize that specifications are given for a range of values, because transistors of the same part number may vary.

H. Carefully cut the top from a transistor case to expose the small transistor within. Use this to show students how delicate transistors are. Follow this discussion by emphasizing transistors' sensitivity to heat, excessive power, and mechanical shock.

I. Review "Impedance and Resonance," Section E, Unit IX in *Introduction to Industrial Electricity-Electronics.*

J. Use the following outline as the basis of a discussion to help students remember the chart of characteristics for transistor circuit configurations in Information Sheet, Section VIII.

1. Voltage gain — High for all except common collector

2. Current gain — High for all except common base

3. Power gain is a combination of current and voltage gain

a. Because common emitter has high voltage and current gain, power gain is very high

b. Because common base has high voltage gain and low current gain, power gain is medium

c. Common collector voltage and current gain combine to make a low power gain

SUGGESTED ACTIVITIES

4. Input impedance

    a. Medium for common emitter

    b. Low for common base

    c. High for common collector

5. Output impedance is opposite of input impedance

    a. Medium for common emitter

    b. High for common base

    c. Low for common collector

6. Phase reversal

    a. Common emitter output is inverted to the input

        EXAMPLE: For the pnp transistor shown on the chart, as the input increases negative voltage in the common emitter circuit, the output will become more positive and vice versa.

    b. Common base and common collector do not invert the output from the input

K. Demonstrate and discuss skills outlined in job sheets.

L. Connect a signal generator to the input of the circuit in Job Sheet #1. Use an oscilloscope to show the amplification between the base and collector. Show that the case of the transistor connects to the collector. Touch the scope probe to the metal case while the circuit is amplifying the waveform.

M. Have available an assortment of functional and defective transistors so that students may complete Job Sheets #3 and #4.

N. Construct a series circuit composed of a transistor connected to collector and base, a microampere meter, and a DC power supply. Use this simple circuit to demonstrate reverse leakage current.

O. Use a soldering iron to heat the transistor in the series circuit described above to demonstrate thermal sensitivity.

P. Give test.

SUGGESTED ACTIVITIES

- Q. Critique test.
- R. Reteach if necessary.

II. Instructional materials

- A. Objective sheet
- B. Suggested activities
- C. Information sheet
- D. Transparency masters
    1. TM #1 — PNP Transistor Majority Current Carriers
    2. TM #2 — Various Transistor Cases
    3. TM #3 — Characteristics of Transistor Circuit Configurations
    4. TM #4 — Collector Characteristic Curve
- E. Assignment sheets
    1. Assignment Sheet #1 — Identify Transistor Types, Leads, and Cases
    2. Assignment Sheet #2 — Calculate Transistor Voltage, Current, and Power Gain
    3. Assignment Sheet #3 — List Various Transistor Circuit Characteristics
- F. Answers to assignment sheets
- G. Job sheets
    1. Job Sheet #1 — Analyze the Common-Emitter Circuit
    2. Job Sheet #2 — Analyze the Common-Base Circuit
    3. Job Sheet #3 — Analyze the Common-Collector Circuit
    4. Job Sheet #4 — Make Various Out-of-Circuit Transistor Checks
    5. Job Sheet #5 — Use a Transistor Tester to Check Transistors
- H. Test
- I. Answers to test

SUGGESTED ACTIVITIES

III. Unit references

A. Alley, Charles L., and Kenneth W. Atwood. *Electronic Engineering,* 3rd ed. New York: John Wiley & Sons, 1973.

B. Chirlian, Paul M. *Electronic Circuits: Physical Principles, Analysis, and Design.* New York: McGraw-Hill Book Company, 1971.

C. *Graphic Symbols for Electrical and Electronics Diagrams.* New York: Institute of Electrical and Electronics Engineers, 1981.

D. Zbar, Paul B., and Joseph G. Sloop. *Electricity-Electronics Fundamentals: A Text-Lab Manual,* 2nd ed. New York: McGraw-Hill Book Company, 1977.

BIPOLAR TRANSISTORS
UNIT III

INFORMATION SHEET

I. Terms and definitions

A. Transistor — Solid-state semiconductor device usually having three terminals; varies conductivity according to voltage and current inputs (Transparency #2)

B. Emitter — Most heavily doped section of transistor where majority current carriers travel inward, and thus are *emitted* into the device (Transparency #1)

C. Collector — Section of transistor in which majority current carriers are *collected* out of the device (Transparency #1)

D. Base — Control section that varies conductivity of the transistor

E. p-material — Semiconductor material in which most of the current is hole flow

F. n-material — Semiconductor material in which most of the current is electron flow

G. Doping — Process of adding current-conducting impurities into crystal materials to make semiconductors

H. Frequency response — Ability of a device to amplify high frequency without distortion

I. Hole — Void in the bonding structure of a semiconductor where an electron can take position

(NOTE: Holes function as if they were positively charged particles flowing in the opposite direction of electrons.)

J. Majority current carriers — Holes or electrons that transfer most of the current within a type of semiconductor material

K. Alpha characteristic — Current transfer ratio for a common-base circuit

L. Beta characteristic — Current transfer ratio for a common-emitter circuit

M. Saturation — State when all normal charge carriers are flowing in a device

N. Cutoff — State when all normal charge carriers stop flowing in a device

INFORMATION SHEET

O. Quiescent point — Point on amplifier characteristic curve representing conditions that exist when input signal is not applied

P. Phase reversal — A change of 180 degrees, or one-half cycle, in phase

Q. Input impedance — Impedance across terminals of a four-terminal network when the output terminals are short-circuited

R. Output impedance — Impedance presented by a source to a load

II. Abbreviations associated with bipolar transistors

A. XSTR — Transistor

B. npn — Transistor having p-material between two sections of n-material

C. pnp — Transistor having n-material between two sections of p-material

D. Q — Schematic designator for transistor

(NOTE: Transistors are usually designated by the letter *Q*, followed by a number to identify them on a schematic, such as Q 101. This is similar to designating resistors by *R*, and diodes by *CR*. The letter *T* was not used because it designates transformers.)

E. Si — Silicon

F. Ge — Germanium

G. α — Alpha

H. B — Beta

I. Δ — Delta, meaning *the change in*

J. A_V — Voltage gain

K. A_I — Current gain

L. A_P — Power gain

M. I_{CBO} — Collector cutoff current, base open

N. I_{CEO} — Collector cutoff current, emitter open

O. E — Emitter

P. B — Base

INFORMATION SHEET

Q. C — Collector

R. V_{CC} — Collector supply voltage

S. V_{BE} — Base-to-emitter voltage

T. V_{BC} — Base-to-collector voltage

U. V_{EC} — Emitter-to-collector voltage

V. I_C — Collector current

W. I_B — Base current

X. I_E — Emitter current

Y. R_L — Load resistance

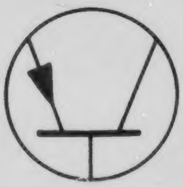
Z. Z — Impedance

III. Transistor circuit symbols (Figures 1 and 2; Assignment Sheet #1)

A. pnp transistor

(NOTE: The pnp transistor is easily remembered by the phrase, "Pointing IN Position.")

FIGURE 1

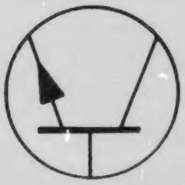


INFORMATION SHEET

B. npn transistor

(NOTE: The npn transistor is easily remembered by the phrase, "Not Pointing iN.")

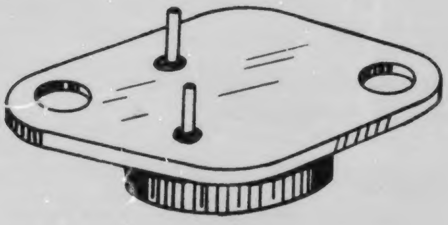
FIGURE 2



IV. Common transistor cases (Figures 3-7; Transparency #2; Assignment Sheet #1)

A. T0-3 case

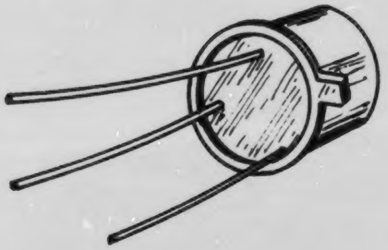
FIGURE 3



INFORMATION SHEET

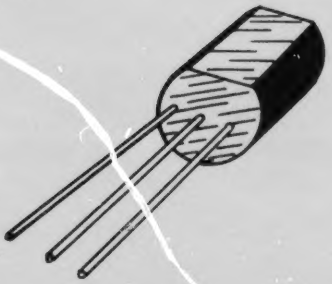
B. T0-5 case

FIGURE 4



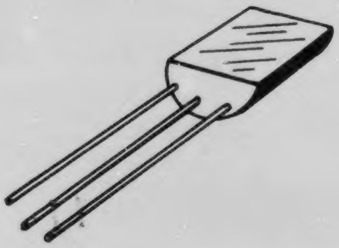
C. T0-20 case

FIGURE 5



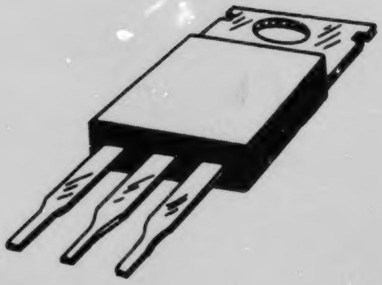
D. T0-23 case

FIGURE 6



E. T0-220 case

FIGURE 7



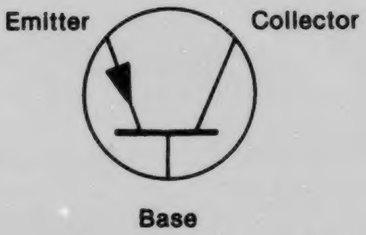
V. Emitter, base, and collector of various transistors (Figures 8 and 9; Assignment Sheet #1)

A. Circuit symbols

(NOTE: The emitter lead in both symbols is the one with the arrowhead.)

1. pnp transistor

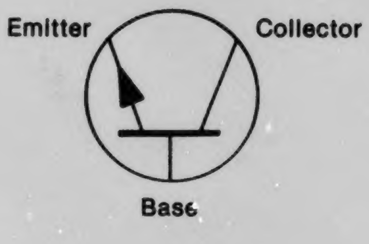
FIGURE 8



INFORMATION SHEET

2. npn transistor

FIGURE 9

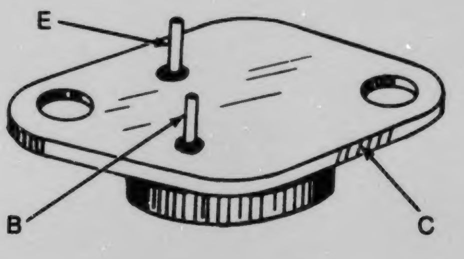


B. Leads for common transistor cases (Figures 10-14)

(NOTE: There are many types of transistor cases identical to those of silicon-controlled rectifiers and field-effect transistors. Because the leads are not standard, it is best to consult a reference manual to determine the leads for the particular part number.)

1. T0-3 case

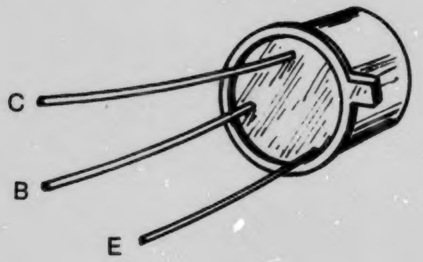
FIGURE 10



INFORMATION SHEET

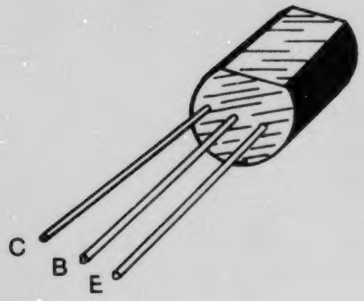
2. T0-5 case

FIGURE 11



3. T0-20 case

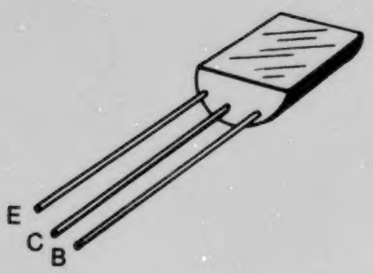
FIGURE 12



INFORMATION SHEET

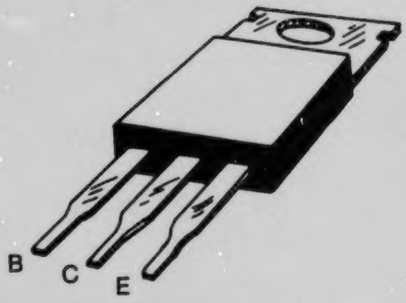
4. T0-23 case

FIGURE 13



5. T0-220 case

FIGURE 14



VI. Characteristics of transistor emitters, bases, and collectors (Transparency #1)

A. Emitters

1. Are most heavily doped section of transistor

2. Have most majority current carriers

3. Carry all current that passes into or out of transistor

4. Are indicated schematically by an arrowhead

INFORMATION SHEET

B. Bases

   1. Are constructed very narrowly to improve transistor frequency response
   2. Control current flow through transistor
   3. Contain material opposite other two sections of transistor
   4. Carry only small portion of current passing into or out of transistor
   5. Are indicated schematically by a perpendicular line

C. Collectors

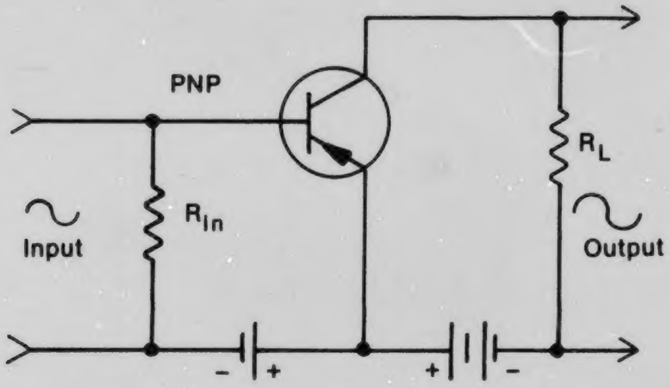
   1. Are often connected to metal case of transistor
   2. Carry large amount of total current into or out of transistor
   3. Are indicated schematically by a diagonal line

VII. Basic transistor circuit configurations (Figures 15-17)

(NOTE: In each configuration, the transistors have a terminal common to both the input and output; this accounts for the circuits' names.)

A. Common-emitter circuit (Job Sheet #1)

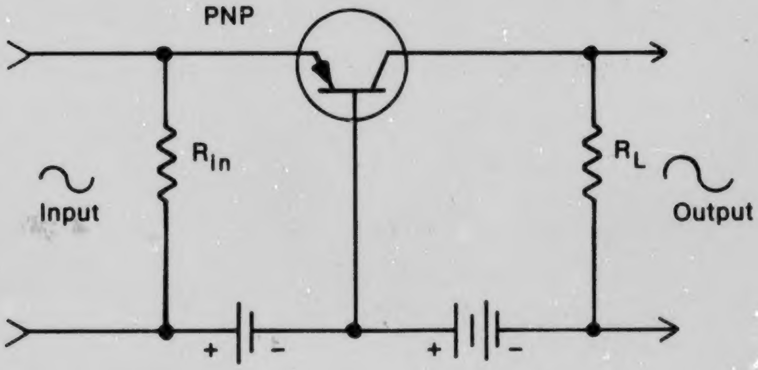
FIGURE 15



INFORMATION SHEET

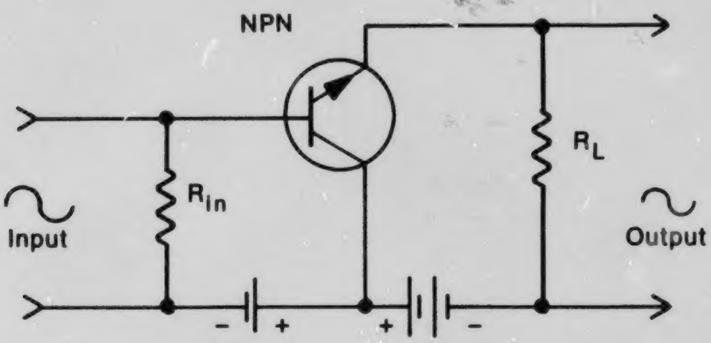
B. Common-base circuit (Job Sheet #2)

FIGURE 16


PNP
R_{in}
Input
R_L
Output
+
−
+
−

C. Common-collector circuit (Job Sheet #3)

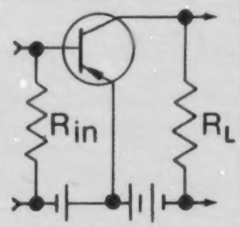
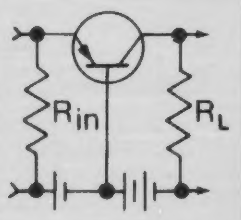
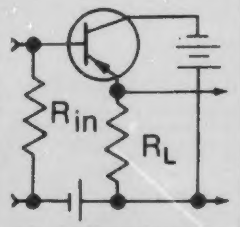
FIGURE 17


NPN
R_{in}
Input
R_L
Output
−
+
+
−

INFORMATION SHEET

VIII. Characteristics of transistor circuit configurations (Table 1)

TABLE 1

			
Characteristics	**Common Emitter**	**Common Base**	**Common Collector**
Voltage Gain (A_V)	High	High	Low
Current Gain (A_I)	High	Low	High
Power Gain (A_P)	Very High	Medium	Low
Input Impedance (Z)	Medium	Low	High
Output Impedance (Z)	Medium	High	Low
Phase Reversal	Yes	No	No

INFORMATION SHEET

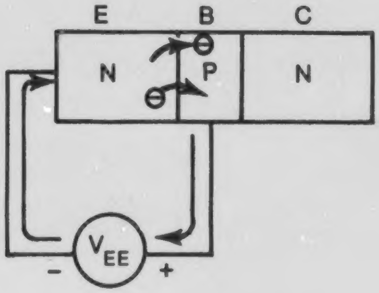
IX. Current flow in external circuits of transistors (Figures 18-23)

A. npn transistors

(NOTE: Because the base is narrow and lightly doped, only about 5 percent of the electrons flow from the emitter through the base. The remaining electrons flow through the base to the collector.)

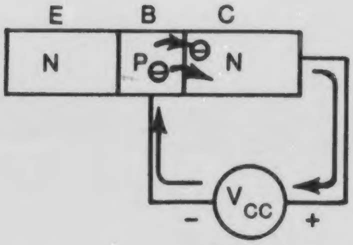
1. Emitter-base junction is forward biased, causing free electrons to flow to base

FIGURE 18



2. Collector-base junction is reverse biased, causing free electrons to flow from base

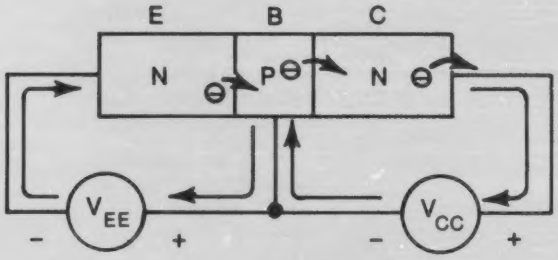
FIGURE 19

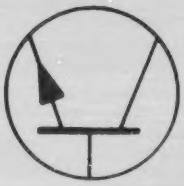


INFORMATION SHEET

3. Free electrons continue to flow from emitter to base and from base to collector, causing current flow through transistor

FIGURE 20



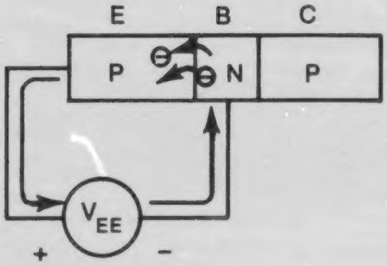


B. pnp transistors

(NOTE: Electron flow always moves opposite the direction of the arrowhead in the transistor schematic symbol. This is also true of diodes. Note also that the base and collector currents both flow through the emitter.)

1. Emitter-base junction is forward biased, causing free electrons to flow from base

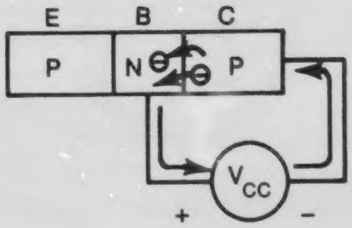
FIGURE 21



INFORMATION SHEET

2. Collector-base junction is reverse biased, causing free electrons to flow to base

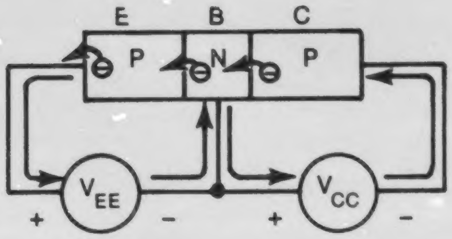
FIGURE 22

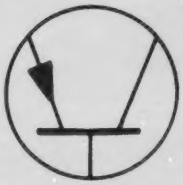


3. Free electrons continue to flow from collector to base and from base to emitter, causing current flow

(NOTE: Because the emitter-base junction is a low resistance region, the small input signal applied to the emitter results in maximum current flow.)

FIGURE 23





X. Bipolar transistor applications

(NOTE: There are many types of transistors other than the simple bipolar transistor. They include phototransistors, field-effect transistors, and unijunction transistors.)

A. Amplifiers

B. Oscillators

C. Regulators

D. Switching circuits

INFORMATION SHEET

XI. Bipolar transistor classifications

A. Polarity

EXAMPLES: npn, pnp

B. Material

EXAMPLES: Silicon, germanium

(NOTE: Germanium is more expensive and is more sensitive to small high-frequency signals than is silicon. Silicon can withstand more current and heat than can germanium.)

C. Case

EXAMPLES: T0-3, T0-5, T0-20

D. Power rating

EXAMPLES: ½ W, 1 W, 25 W

E. Part number

EXAMPLES: 2N1305, 2N6402, SK3025

(NOTE: Diodes often have part numbers beginning with 1N, and transistors often have part numbers beginning with 2N. The part number specifies all other classifications. Part number suffixes, such as the letter *A*, indicate improved capabilities.)

F. Application

EXAMPLES: High-speed switching, high-frequency response, high gain

XII. Calculating transistor voltage, current, and power gain (Assignment Sheet #2)

A. Voltage gain (A_V) — The ratio of output voltage to input voltage; divide output voltage by input voltage

EXAMPLE: A transistor circuit has an input voltage of 0.2 volts and an output voltage of 7.0 volts. The voltage gain will be 35.

$$A_V = V_{out} \div V_{in}$$

$$= \frac{7.0\ V}{0.2\ V}$$

$$= 35$$

INFORMATION SHEET

B. Current gain (A_I) — The ratio of output current to input current; divide output current by input current

EXAMPLE: A transistor circuit has an input current of 2 microamperes and an output current of 200 microamperes. The current gain will be 100.

$$\begin{aligned} A_I &= I_{out} \div I_{in} \\ &= \frac{200\ \mu A}{2\ \mu A} \\ &= 100 \end{aligned}$$

C. Power gain (A_P) — The ratio of output power to input power; multiply voltage gain by current gain

EXAMPLES: A common-emitter transistor circuit has a voltage gain of 35 and a current gain of 75. The power gain will be 2,625.

$$\begin{aligned} A_P &= A_V \times A_I \\ &= 35 \times 75 \\ &= 2{,}625 \end{aligned}$$

A transistor has an input power of 100 milliwatts and an output power of 5 watts. The power gain will be 50.

$$\begin{aligned} A_P &= P_{out} \div P_{in} \\ &= \frac{5\ W}{100\ mW} \\ &= \frac{5000\ mW}{100\ mW} \\ &= 50 \end{aligned}$$

XIII. Calculating alpha and beta values for common-emitter and common-base circuits (Assignment Sheet #3)

A. Alpha

1. Divide change in collector current by change in emitter current, with base-to-emitter voltage constant

INFORMATION SHEET

2. Solve for alpha, given collector current and emitter current

EXAMPLE: A common-base circuit has a change in collector current of 0.78 milliamperes and a change in emitter current of 0.8 milliamperes. The alpha value will be 0.975.

$$\alpha = \left. \Delta I_C \div \Delta I_E \right| V_{BC} \text{ constant}$$

$$= \frac{0.78 \text{ mA}}{0.8 \text{ mA}}$$

$$= 0.975$$

(NOTE: In junction transistors, the alpha value is always less than unity or 1; it usually ranges from 0.95 to 0.98.)

B. Beta

1. Divide change in collector current by change in base current, with emitter-to-collector voltage constant

2. Solve for beta, given collector current and base current

EXAMPLE: A common-emitter circuit has a change in collector current of 2 milliamperes and a change in base current of 0.08 milliamperes. The beta value will be 25.

$$B = \left. \Delta I_C \div \Delta I_B \right| V_{EC} \text{ constant}$$

$$= \frac{2 \text{ mA}}{0.08 \text{ mA}}$$

$$= 25$$

(NOTE: In the junction transistor, beta is always greater than 1. Beta values of 20 to 30 usually indicate a power transistor, and beta values of approximately 200 indicate small-signal, low-power transistors.)

XIV. Construction of transistor load lines (Transparency #3)

(NOTE: A transistor load line is a line drawn on a collector characteristic curve in which the operating point of the transistor moves as the collector current changes. The slope of the line depends upon the collector load resistance.)

A. Determine type of transistor being used

EXAMPLE: 2N1491

INFORMATION SHEET

B. Locate a collector characteristic curve by using a transistor manual or manufacturer's specification sheet

C. Determine collector supply voltage (V_{CC}) utilized in circuit; mark this point "A" on the horizontal axis (V_{CE}) of characteristic curve

D. Determine load resistance value in collector supply circuit of transistor; divide this resistance into the collector supply voltage

E. Mark this point "B" on the vertical axis (I_C) of characteristic curve

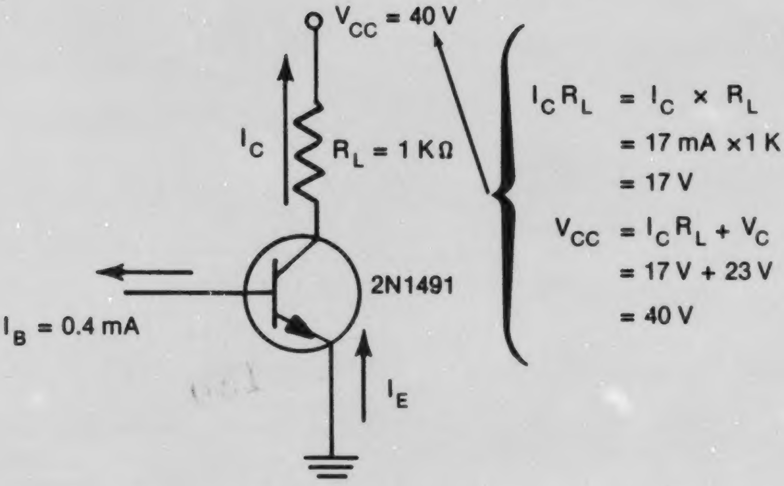
F. Draw a straight line between points A and B

G. Mark the quiescent point at point where load line intersects collector curve for base bias current (I_{BB})

(NOTE: This point is often chosen as a midpoint between saturation and cutoff of the collector current.)

EXAMPLE: In a 2N1491 transistor in a circuit where collector supply voltage is 40 volts, load resistance is 1 kohm, and base current is 0.4 milliamperes (Figure 24), the load line intersects the collector curve for base bias current at the 23-volt point.

FIGURE 24



INFORMATION SHEET

XV. Transistor characteristics indicated by arrowhead symbol

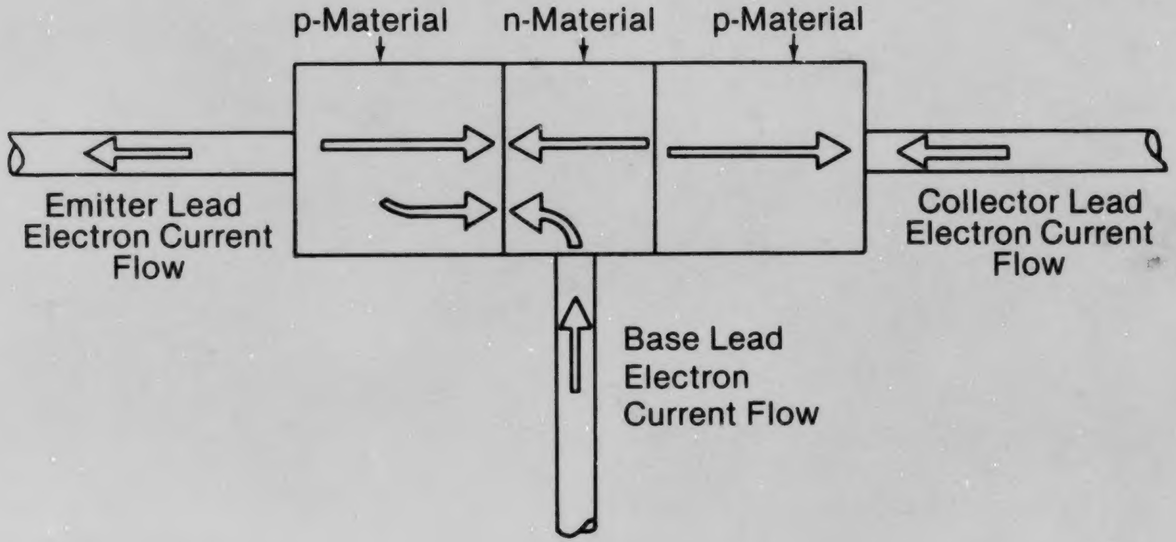
    A. Arrowhead is always on emitter line

    B. Arrow points in direction of n-type material

    C. Current always flows against arrow

    D. Arrow (emitter) lead carries sum of base and collector currents

PNP Transistor Majority Current Carriers



p-Material

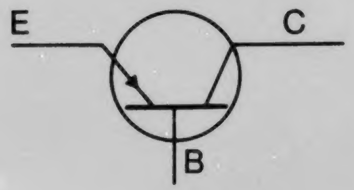
n-Material

p-Material

Emitter Lead Electron Current Flow

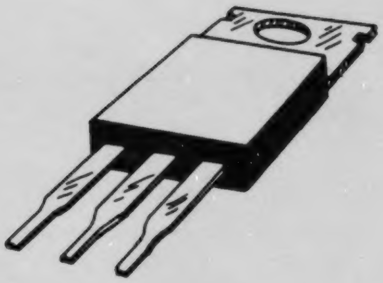
Collector Lead Electron Current Flow

Base Lead Electron Current Flow

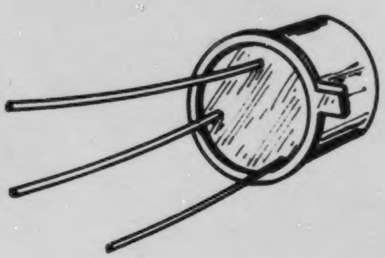


Various Transistor Cases

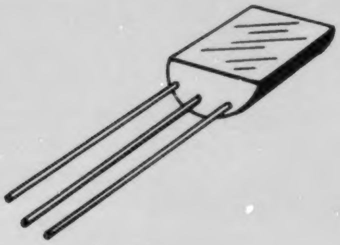
TO-220 Case



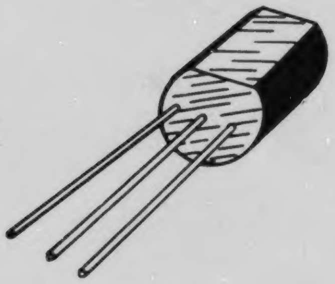
TO-5 Case



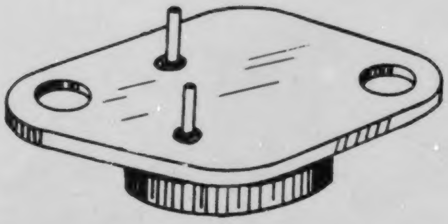
TO-23 Case



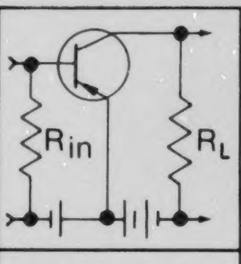
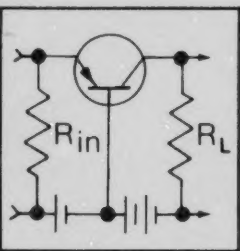
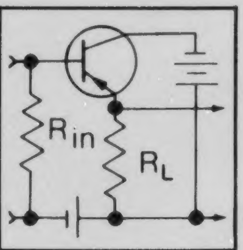
TO-20 Case



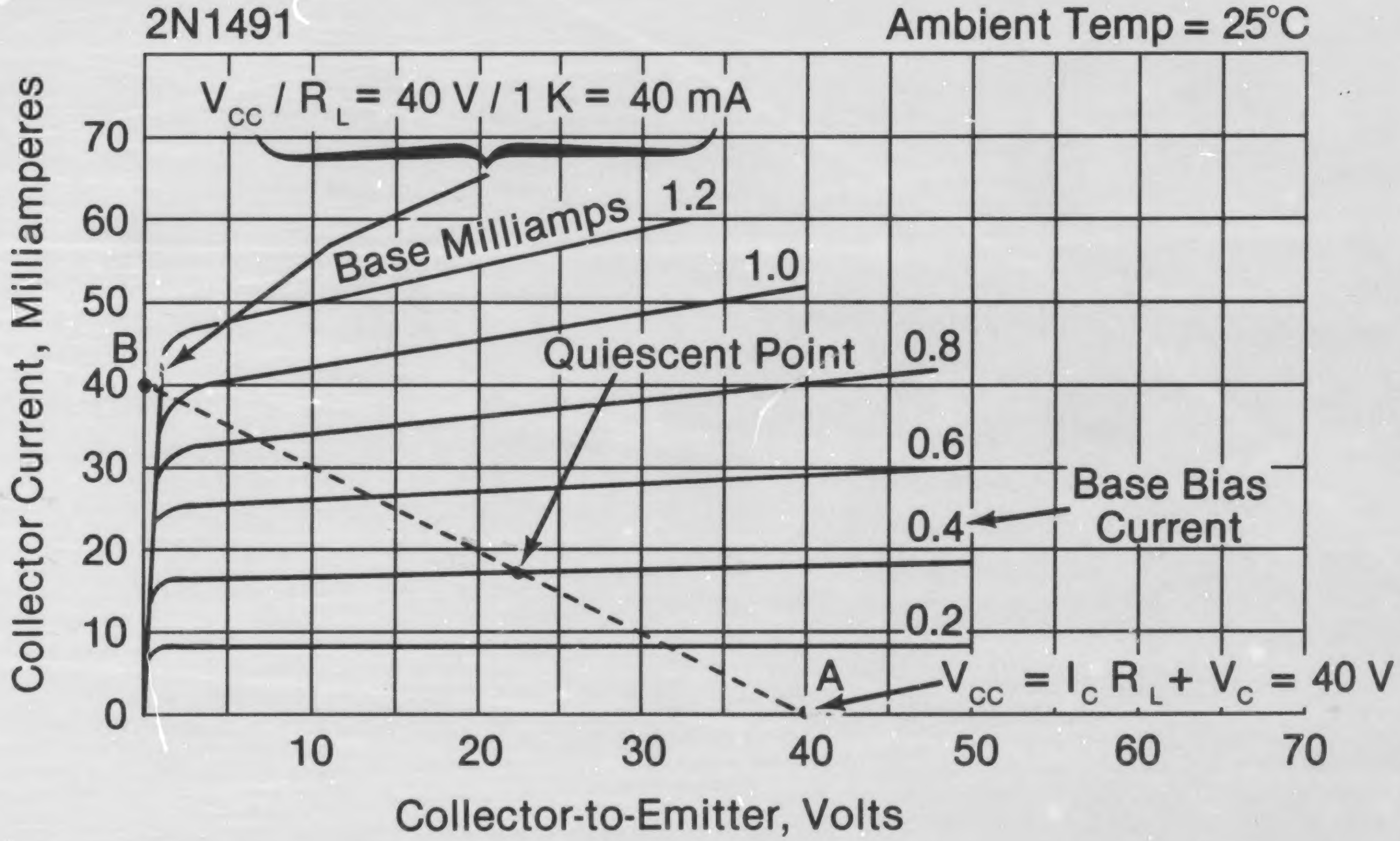
TO-3 Case



Characteristics of Transistor Circuit Configurations

			
Character-istics	**Common Emitter**	**Common Base**	**Common Collector**
Voltage Gain (A_V)	High 300 V	High 500 V	Low Less Than 1 V
Current Gain (A_I)	High 50 V	Low 0.97 V	High 50 V
Power Gain (A_P)	Very High 12 kV	Medium 400 V	Low 30 V
Input Impedance (Z)	Medium 1 KΩ	Low 60 Ω	High 400 KΩ
Output Impedance (Z)	Medium 50 KΩ	High 1 MΩ	Low 100 Ω
Phase Reversal	Yes	No	No

Collector Characteristic Curve



TM #4

GIE - 151-A

BIPOLAR TRANSISTORS
UNIT III

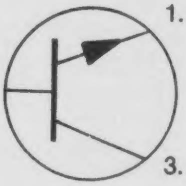
ASSIGNMENT SHEET #1 — IDENTIFY TRANSISTOR TYPES, LEADS, AND CASES

NAME ______________________________ SCORE ____________

In order to troubleshoot transistor circuits effectively, a technician must be able to identify circuit symbols and component leads.

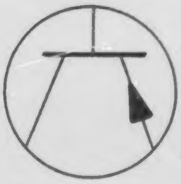
In the spaces provided, label the emitter, base, and collector leads "E," "B," and "C," and name the type of transistor polarity (npn or pnp) or case, when indicated.

A.



1. ______________________
2. ______________________
3. ______________________
4. Polarity ______________________

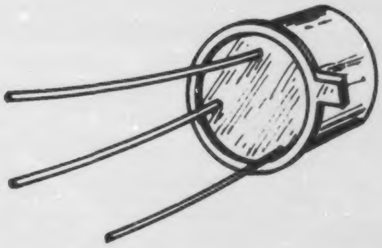
B.



1. ______________________
2. ______________________
3. ______________________
4. Polarity ______________________

ASSIGNMENT SHEET #1

C. T0-_____ case

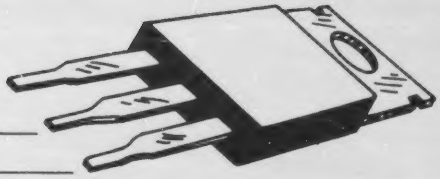


1. ______________________________

2. ______________________________

3. ______________________________

D. T0-_____ case

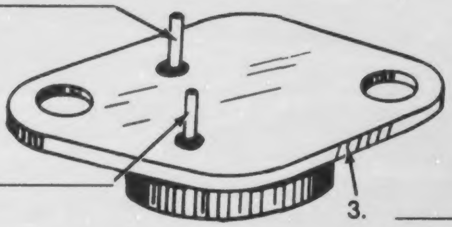


1. ______________________________

2. ______________________________

3. ______________________________

E. T0-_____ case



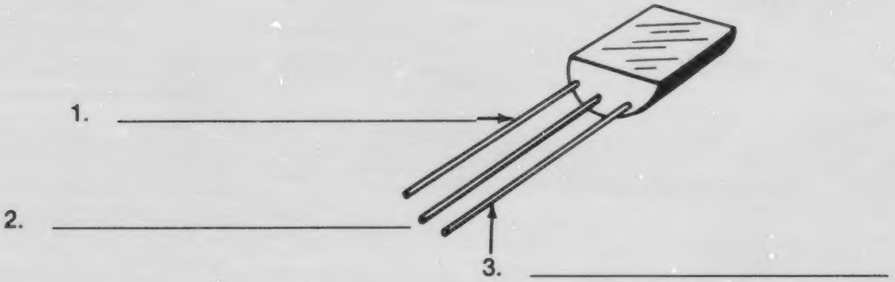
1. ______________________________

2. ______________________________

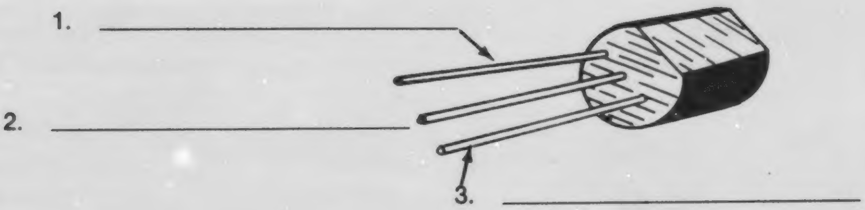
3. ______________________________

ASSIGNMENT SHEET #1

F. T0-_____ case



G. T0-_____ case



BIPOLAR TRANSISTORS
UNIT III

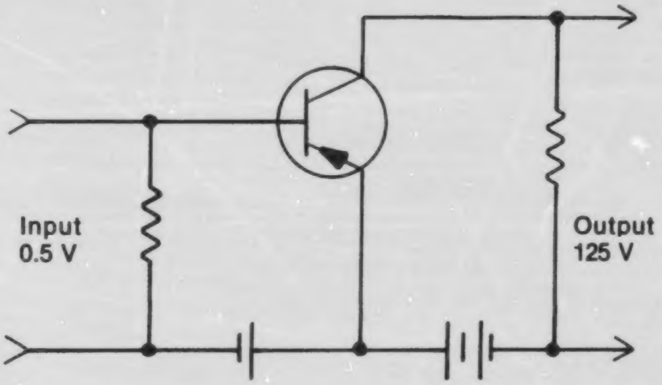
ASSIGNMENT SHEET #2 — CALCULATE TRANSISTOR VOLTAGE, CURRENT, AND POWER GAIN

NAME ______________________________ SCORE ______________

As an electronics technician, you will find it necessary for troubleshooting purposes to calculate gain in transistor circuits.

Determine the gain in the following circuits and indicate whether the circuit is a common base, common emitter, or common collector.

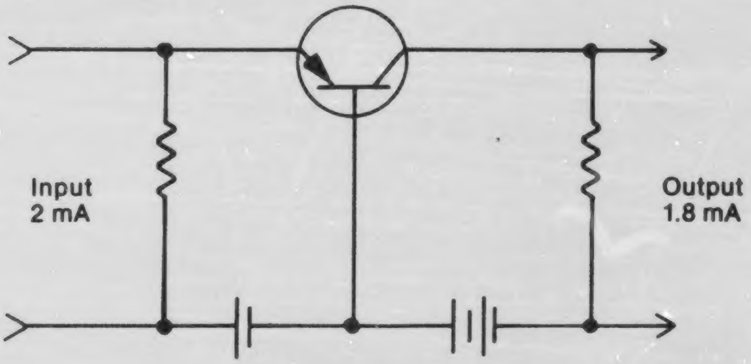
A.



1. A_V = ______________________________

2. Type circuit ______________________________

B.

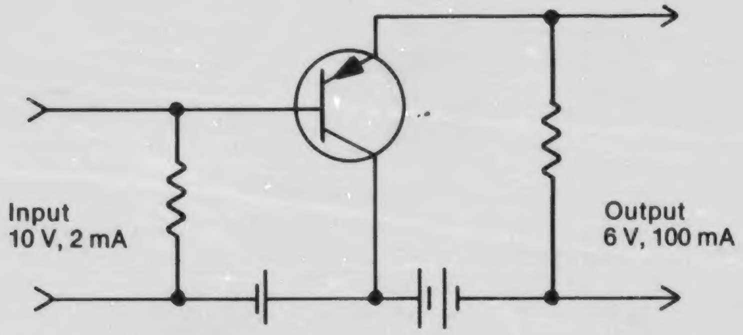


1. A_I = ______________________________

2. Type circuit ______________________________

ASSIGNMENT SHEET #2

C.


Input
10 V, 2 mA
Output
6 V, 100 mA

1. A_P = ______________________

2. Type circuit ______________________

D. 1. What is the input impedance of the circuit in question C?

Input impedance (Z) = ______________________

2. What is the output impedance?

Output impedance (Z) = ______________________

3. Do these readings compare with the characteristics of this type circuit? _____

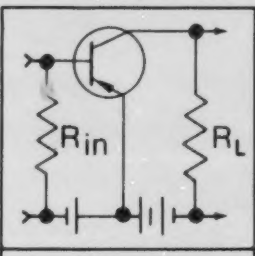
Why or why not? ______________________

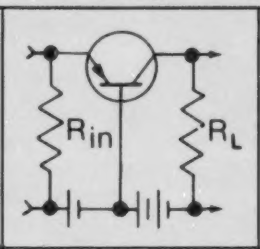
BIPOLAR TRANSISTORS
UNIT III

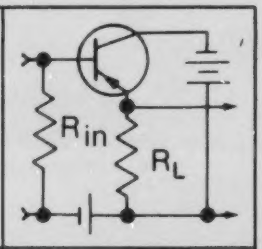
ASSIGNMENT SHEET #3 — LIST VARIOUS TRANSISTOR CIRCUIT CHARACTERISTICS

NAME ______________________________ SCORE ______________

When troubleshooting a circuit, the electronics technician must be able to anticipate voltage, current, and power gain, and the amount of input and output impedance in various transistor circuits. The technician must also be able to determine whether or not there is phase reversal. On the chart below, list high, medium, and low characteristics of each specified transistor circuit. Write "yes" for phase reversal, and "no" if there is no phase reversal.







Characteristics	Common Emitter	Common Base	Common Collector
Voltage Gain (A_V)			
Current Gain (A_I)			
Power Gain (A_P)			
Input Impedance (Z)			
Output Impedance (Z)			
Phase Reversal			

BIPOLAR TRANSISTORS
UNIT III

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

A.
1. E
2. B
3. C
4. npn

B.
1. B
2. E
3. C
4. pnp

C. T0-5 case
1. C
2. B
3. E

D. T0-220 case
1. B
2. C
3. E

E. T0-3 case
1. E
2. B
3. C

F. T0-23 case
1. E
2. C
3. B

G. T0-20 case
1. C
2. B
3. E

Assignment Sheet #2

A.
1. 250
2. Common emitter

ANSWERS TO ASSIGNMENT SHEETS

B. 1. 0.9

2. Common base

C. 1. 30

2. Common collector

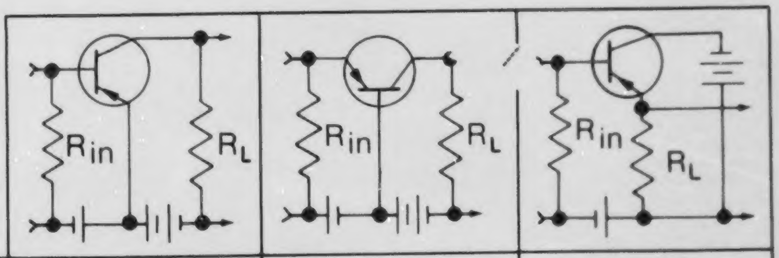
D. 1. 5 kohms

2. 60 ohms

3. Yes

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #3



Characteristics	Common Emitter	Common Base	Common Collector
Voltage Gain (A_V)	High	High	Low
Current Gain (A_I)	High	Low	High
Power Gain (A_P)	Very High	Medium	Low
Input Impedance (Z)	Medium	Low	High
Output Impedance (Z)	Medium	High	Low
Phase Reversal	Yes	No	No

BIPOLAR TRANSISTORS
UNIT III

JOB SHEET #1 — ANALYZE THE COMMON-EMITTER CIRCUIT

I. Equipment and materials

- A. DC power supply
- B. Two ammeters, 0 to 5 milliampere
- C. Multimeter
- D. Transistor, 2N1304 or equivalent
- E. Resistor, 4.7 kohm
- F. Resistor, 47 kohm
- G. Resistor, 220 ohm
- H. Potentiometer, 4.7 kohm
- I. Potentiometer, 220 ohm
- J. Breadboard

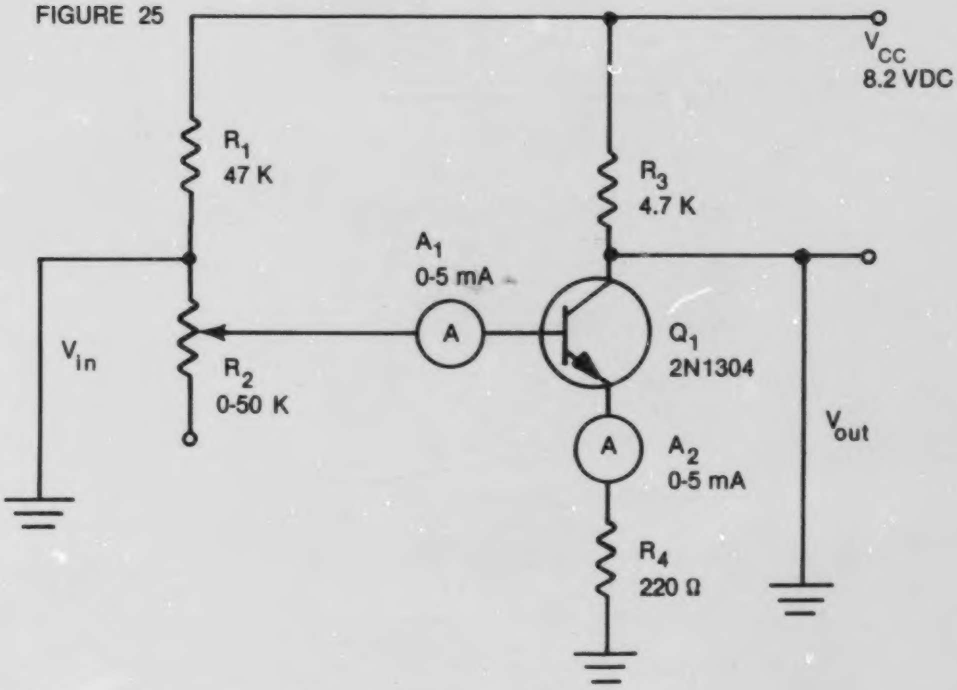
JOB SHEET #1

II. Procedure

A. Construct circuit as shown in Figure 25

(NOTE: Have instructor check circuit.)

FIGURE 25



V_{CC}
8.2 VDC
R_1
47 K
R_3
4.7 K
A_1
0-5 mA
A
Q_1
2N1304
V_{in}
R_2
0-50 K
A
A_2
0-5 mA
V_{out}
R_4
220 Ω

B. Turn potentiometer R2 for minimum resistance

C. Adjust the DC power supply for 8.2 VDC

D. Measure input voltage

V_{in} = ______________________

E. Determine voltage drop across R1 ______________; the calculated R1 voltage should be

V_{R_1} = ______________________

F. Using V_{in} multimeter, measure voltage drop across R1 and record below

V_{R_1} = ______________________

Is this value comparable with that obtained in step E? ______________

G. Calculate base current, using the above readings

I_B = ______________________ mA

JOB SHEET #1

H. Using ammeter in base circuit, measure base current

I_B = ____________________ mA

I. Does reading in step H compare with reading in step G? ____________

J. Measure output voltage

V_{out} = ____________________

K. Is transistor in the circuit conducting or cutoff? ____________________

L. What voltage output should be measured if circuit is at conducting or at cutoff?

Conducting = ____________________ Cutoff = ____________________

(NOTE: This is an important measurement used in troubleshooting transistor circuits.)

M. While observing output voltage, short the base-to-emitter; leave the short only as long as necessary to observe meter indication

(CAUTION: Do not short any other part of the circuit.)

N. Does the base-emitter short cause any change in output voltage? ______

If so, what? ____

____

O. Using the values obtained from the previous steps, calculate voltage across R3

V_{R_3} = ____________________

P. Calculate value of collector current

I_C = ____________________ mA

Q. Calculate voltage gain

A_V = ____________________

R. Calculate current gain

A_I = ____________________

S. Calculate power gain

A_P = ____________________

JOB SHEET #1

T. Position potentiometer for maximum resistance and determine the following values

(NOTE: In the bipolar transistor, a change in base current causes a change in the emitter current.)

V_{CC} = ____________________

V_{in} = ____________________

V_{R_1} = ____________________

I_B = ____________________

V_{out} = ____________________

V_{R_3} = ____________________

I_C = ____________________

A_V = ____________________

A_I = ____________________

A_P = ____________________

U. Calculate collector current change when R2 is at minimum resistance

ΔI_C = ____________________

V. Calculate collector current change when R2 is at maximum resistance

ΔI_C = ____________________

W. Calculate base current change when R2 is at minimum resistance

ΔI_B = ____________________

X. Calculate base current change when R2 is at maximum resistance

ΔI_B = ____________________

Y. Calculate current gain

A_I = ____________________

(NOTE: The manufacturer lists the current gain of all transistors. Compare this reading with the reading obtained above. Your reading will not compare to the book value. The book value is given for a specific test circuit which differs from this circuit. Discuss your results with the instructor.)

Z. Disconnect circuit and put away equipment and materials

BIPOLAR TRANSISTORS
UNIT III

JOB SHEET #2 — ANALYZE THE COMMON-BASE CIRCUIT

I. Equipment and materials

   A. DC power supply

   B. Two ammeters, 0 to 5 milliampere

   C. Multimeter

   D. Transistor, 2N1304 or equivalent

   E. Resistor, 4.7 kohm

   F. Resistor, 47 kohm

   G. Resistor, 220 ohm

   H. Potentiometer, 0 to 50 kohm

   I. Breadboard

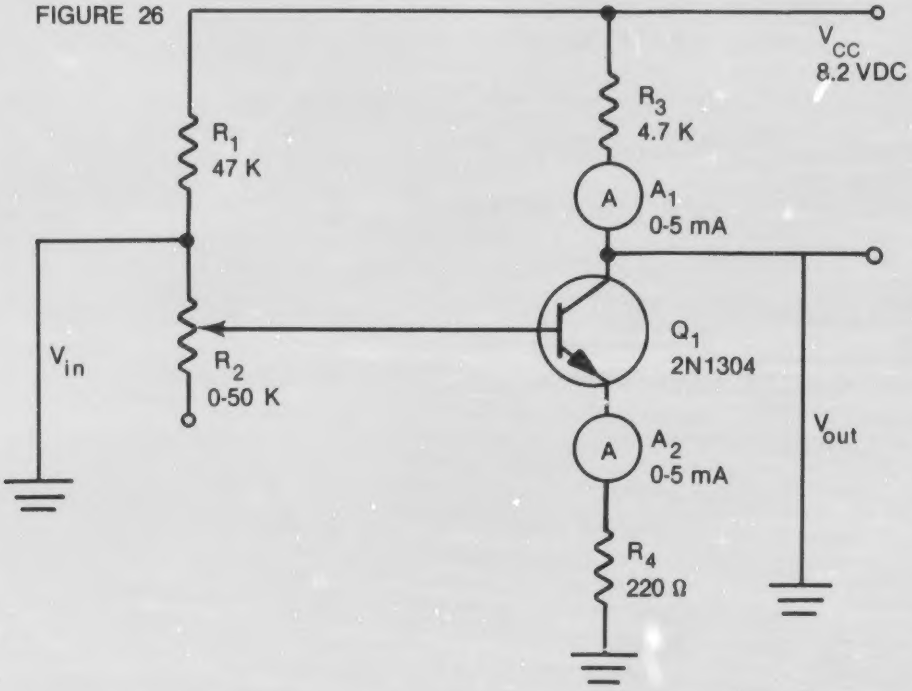
JOB SHEET #2

II. Procedure

A. Construct circuit as shown in Figure 26

(NOTE: Have instructor check circuit.)

FIGURE 26



V_{CC}
8.2 VDC
R_3
4.7 K
R_1
47 K
A
A_1
0-5 mA
V_{in}
R_2
0-50 K
Q_1
2N1304
V_{out}
A
A_2
0-5 mA
R_4
220 Ω

B. Turn potentiometer R2 for minimum resistance

C. Adjust the DC power supply for 8.2 VDC

D. Measure input voltage

V_{in} = ____________________

E. Determine voltage drop across R1 ____________; the calculated R1 voltage should be

V_{R_1} = ____________________

F. Using V_{in} multimeter, measure voltage drop across R1 and record below

V_{R_1} = ____________________

Is this value comparable with that obtained in step E? ______________

G. Calculate base current, using the above readings

I_B = ____________________ mA

JOB SHEET #2

H. Using ammeter in base circuit, measure base current

I_B = ____________________ mA

I. Does reading in step H compare with reading in step G? _____________

J. Measure output voltage

V_{out} = ____________________

K. Is transistor in the circuit conducting or cutoff? ____________________

L. What voltage output should be measured if circuit is at conducting or at cutoff?

Conducting = ____________________ Cutoff = ____________________

(NOTE: This is an important measurement used in troubleshooting transistor circuits.)

M. While observing output voltage, short the base-to-emitter; leave the short only as long as necessary to observe meter indication

(CAUTION: Do not short any other part of the circuit.)

N. Does the base-emitter short cause any change in output voltage?_______

If so, what? ____

____

O. Using the values obtained from the previous steps, calculate voltage across R3

V_{R_3} = ____________________

P. Calculate value of collector current

I_C = ____________________

Q. Calculate voltage gain

A_V = ____________________

R. Calculate current gain

A_I = ____________________

S. Calculate power gain

A_P = ____________________

JOB SHEET #2

T. Position potentiometer for maximum resistance and determine the following values

(NOTE: In the bipolar transistor, a change in base current causes a change in the emitter current.)

V_{CC} = ______________________

V_{in} = ______________________

V_{R_1} = ______________________

I_B = ______________________

V_{out} = ______________________

V_{R_3} = ______________________

I_C = ______________________

A_V = ______________________

A_I = ______________________

A_P = ______________________

U. Calculate collector current change when R2 is at minimum resistance

ΔI_C = ______________________

V. Calculate collector current change when R2 is at maximum resistance

ΔI_C = ______________________

W. Calculate base current change when R2 is at minimum resistance

ΔI_B = ______________________

X. Calculate base current change when R2 is at maximum resistance

ΔI_B = ______________________

Y. Calculate current gain

A_I = ______________________

(NOTE: The manufacturer lists the current gain of all transistors. Compare this reading with the reading obtained above. Your reading will not compare to the book value. The book value is given for a specific test circuit which differs from this circuit. Discuss your results with the instructor.)

Z. Disconnect circuit and put away equipment and materials

BIPOLAR TRANSISTORS
UNIT III

JOB SHEET #3 — ANALYZE THE COMMON-COLLECTOR CIRCUIT

I. Equipment and materials

A. DC power supply

B. Two ammeters, 0 to 5 milliampere

C. Multimeter

D. Transistor, 2N1305

E. Resistor, 4.7 kohm

F. Resistor, 47 kohm

G. Resistor, 220 ohm

H. Potentiometer, 0 to 50 kohm

I. Breadboard

J. Test leads

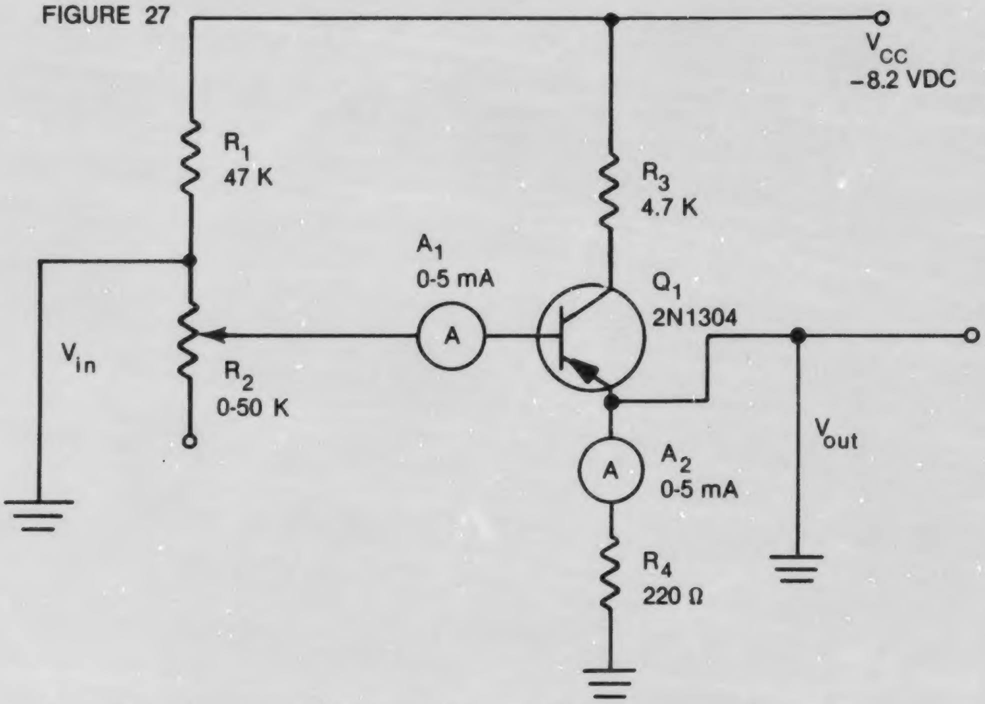
JOB SHEET #3

II. Procedure

A. Construct circuit as shown in Figure 27

(NOTE: Have instructor check circuit.)

FIGURE 27



V_{CC}
−8.2 VDC
R_1
47 K
R_3
4.7 K
A_1
0-5 mA
A
Q_1
2N1304
V_{in}
R_2
0-50 K
V_{out}
A
A_2
0-5 mA
R_4
220 Ω

B. Turn potentiometer R2 for minimum resistance

C. Adjust DC power supply for −8.2 VDC

D. Measure input voltage

V_{in} = ____________________

E. Calculate voltage drop across R1

V_{R_1} = ____________________

F. Using the V_{in} multimeter, measure voltage drop across R1 and record below

V_{R_1} = ____________________

Does this value compare with that obtained in step E? ______________

G. Calculate base current, using the above readings

I_B = ____________________ mA

JOB SHEET #3

H. Using ammeter in base circuit, measure base current

I_B = ______________________ mA

I. Does reading in step H compare with reading in step G? ______________

J. Measure output voltage

V_{out} = ______________________

K. Is transistor in circuit conducting or cutoff? _________________________

L. What voltage output should be measured if circuit is conducting or at cutoff?

Conducting = ______________________ Cutoff = ____________________

M. While observing output voltage, short the base-to-emitter; leave the short only as long as necessary to observe meter indication

(CAUTION: Do not short any other part of the circuit.)

N. Does the base-emitter short cause any change in output voltage? ______

If so, what? ____

____

O. Calculate voltage drop across R3

V_{R_3} = ______________________

P. Calculate value of collector current

I_C = ______________________

Q. Calculate voltage gain

A_V = ______________________

R. Calculate current gain

A_i = ______________________

JOB SHEET #3

S. Calculate power gain

A_p = ____________________

T. Do the values in steps Q, R, and S compare with the values given for this type circuit? ____

(NOTE: Discuss your results with the instructor.)

U. Disconnect circuit and put away equipment and materials

BIPOLAR TRANSISTORS
UNIT III

JOB SHEET #4 — MAKE VARIOUS OUT-OF-CIRCUIT TRANSISTOR CHECKS

I. Equipment and materials

   A. Multimeter with test leads

   B. Assortment of functional and defective transistors

II. Procedure

   A. Check each transistor with multimeter each direction between each two pairs of leads

   B. Separate transistors into two groups: those that you believe are defective and those that you believe are functional

   C. Measure resistance from the case to collector lead on those transistors with metal cases in the functional group

   (NOTE: Discuss your results with the instructor.)

   D. Put equipment and materials away

BIPOLAR TRANSISTORS
UNIT III

JOB SHEET #5 — USE A TRANSISTOR TESTER TO CHECK TRANSISTORS

I. Equipment and materials

   A. Transistor tester with instructions for operation

   B. Assortment of functional and defective transistors

II. Procedure

   A. Review operating instructions for transistor tester

   B. Test transistors and separate the defective ones from the functional ones

   (NOTE: Discuss your results with the instructor.)

   C. Put equipment and materials away

BIPOLAR TRANSISTORS
UNIT III

TEST

NAME ______________________________ SCORE ______________

1. Match terms associated with bipolar transistors to their correct definitions. Write the correct numbers in the blanks.

_____a. A change of 180 degrees, or one-half cycle, in phase

_____b. Most heavily doped section of transistor where majority current carriers travel inward, and thus are *emitted* into the device

_____c. Section of transistor in which majority current carriers are *collected* out of the device

_____d. Solid-state semiconductor device usually having three terminals; varies conductivity according to voltage and current inputs

_____e. Control section that varies conductivity of the transistor

_____f. Process of adding current-conducting impurities into crystal materials to make semiconductors

_____g. Semiconductor material in which most of the current is hole flow

_____h. Ability of a device to amplify high frequency without distortion

_____i. Semiconductor material in which most of the current is electron flow

_____j. Void in the bonding structure of a semiconductor where an electron can take position

_____k. Holes or electrons that transfer most of the current within a type of semiconductor material

1. Collector
2. Transistor
3. Emitter
4. Phase reversal
5. p-material
6. Base
7. Doping
8. n-material
9. Hole
10. Frequency response
11. Majority current carriers

TEST

______l. Point on amplifier characteristic curve representing conditions that exist when input signal is not applied

______m. State when all normal charge carriers are flowing in a device

______n. Impedance across terminals of a four-terminal network when the output terminals are short-circuited

______o. Current transfer ratio for a common-base circuit

______p. State when all normal charge carriers stop flowing in a device

______q. Impedance presented by a source to a load

______r. Current transfer ratio for a common-emitter circuit

12. Quiescent point
13. Output impedance
14. Alpha characteristic
15. Cutoff
16. Beta characteristic
17. Saturation
18. Input impedance

2. Match abbreviations associated with bipolar transistors to their correct interpretations. Write the correct numbers in the blanks.

______a. Silicon

______b. Germanium

______c. Alpha

______d. Schematic designator for transistor

______e. Transistor having n-material between two sections of p-material

______f. Transistor

______g. Transistor having p-material between two sections of n-material

______h. Beta

______i. Power gain

______j. Delta, meaning *the change in*

1. npn
2. Q
3. Si
4. XSTR
5. Ge
6. α
7. B
8. Δ
9. A_P
10. pnp

TEST

______k. Current gain

______l. Collector

______m. Emitter

______n. Voltage gain

______o. Collector cutoff current, emitter open

______p. Base

______q. Collector cutoff current, base open

______r. Collector supply voltage

______s. Emitter current

______t. Emitter-to-collector voltage

______u. Collector current

______v. Base-to-emitter voltage

______w. Impedance

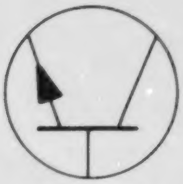
______x. Load resistance

______y. Base-to-collector voltage

______z. Base current

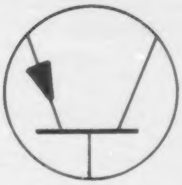
11. A_V
12. A_I
13. I_{CEO}
14. B
15. E
16. C
17. I_{CBO}
18. V_{CC}
19. V_{BE}
20. V_{BC}
21. V_{EC}
22. I_C
23. I_B
24. I_E
25. R_L
26. Z

3. Label transistor circuit symbols. Write the correct names in the blanks.



a. ____

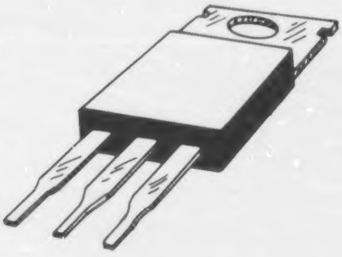
TEST

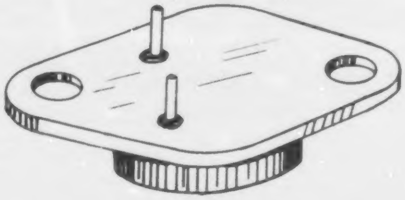


b. ______________________________

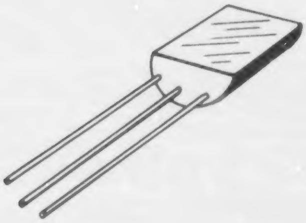
4. Identify common transistor cases. Write the correct names in the blanks.

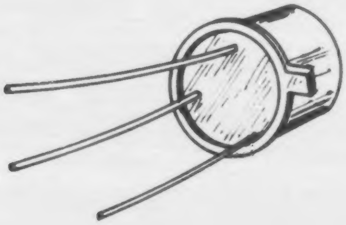
T0-3 case
T0-20 case
To-23 case
T0-220 case
T0-5 case





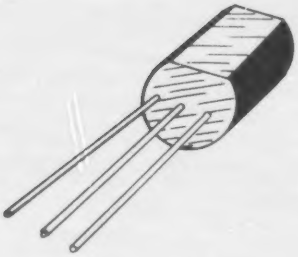
a. ______________________ b. ______________________





c. ______________________ d. ______________________

TEST

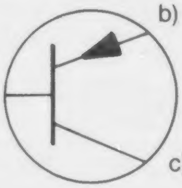


e. ______________________________

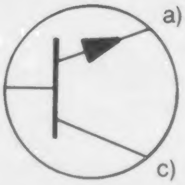
5. Identify the emitter, base, and collector of various transistors. Write the correct names in the blanks.

   a. Circuit symbols

      1) pnp transistor



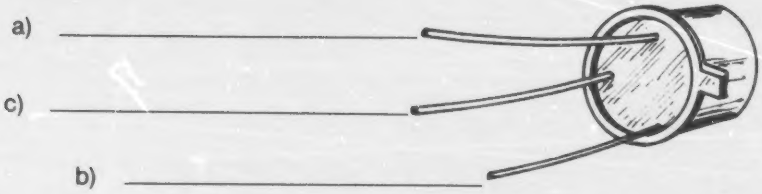
      2) npn transistor



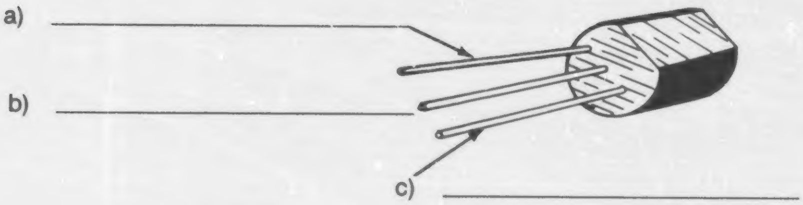
TEST

b. Common transistors

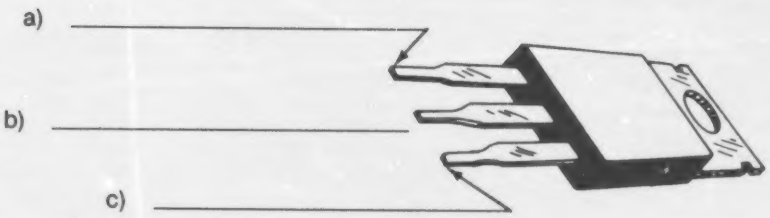
1) T0-5 case



2) T0-20 case

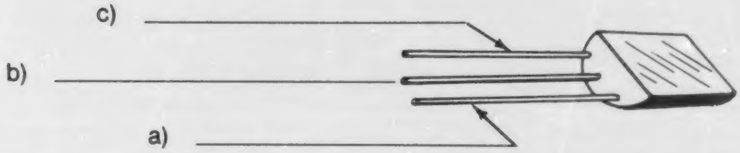


3) T0-220 case

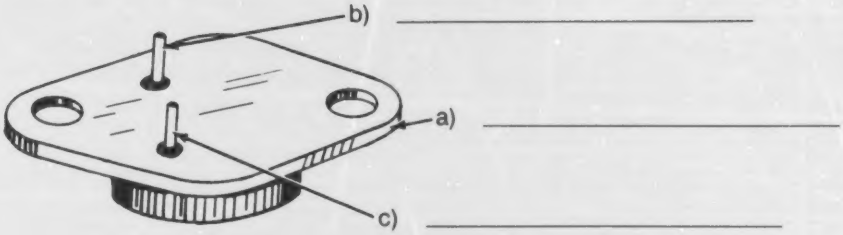


TEST

4) T0-23 case



5) T0-3 case



6. Select from the following list characteristics of transistor emitters, bases, and collectors. Write an "E" in the blanks before emitter, a "B" before base, and a "C" before collector.

_____a. Are most heavily doped section of transistor

_____b. Are constructed very narrowly to improve transistor frequency response

_____c. Are indicated schematically by a diagonal line

_____d. Carry large amount of total current into or out of transistor

_____e. Are indicated schematically by a perpendicular line

_____f. Have most majority current carriers

_____g. Are indicated schematically by an arrowhead

_____h. Control current flow through transistor

_____i. Are often connected to metal case of transistor

_____j. Carry all current that passes into or out of transistor

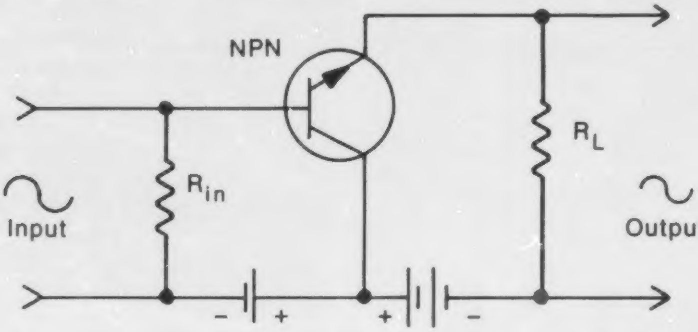
_____k. Contain material opposite other two sections of transistor

_____l. Carry only small portion of current passing into or out of transistor

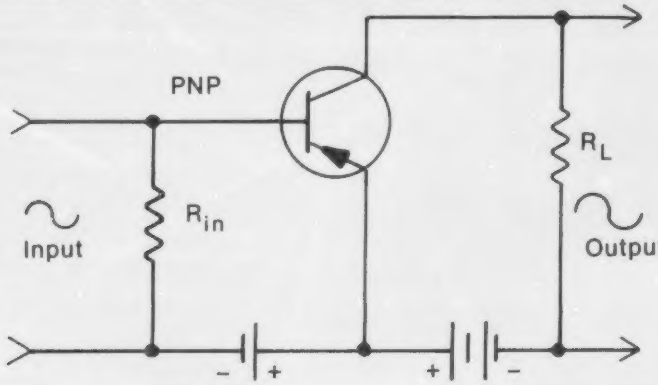
TEST

7. Identify basic transistor circuit configurations. Write the correct names in the blanks.

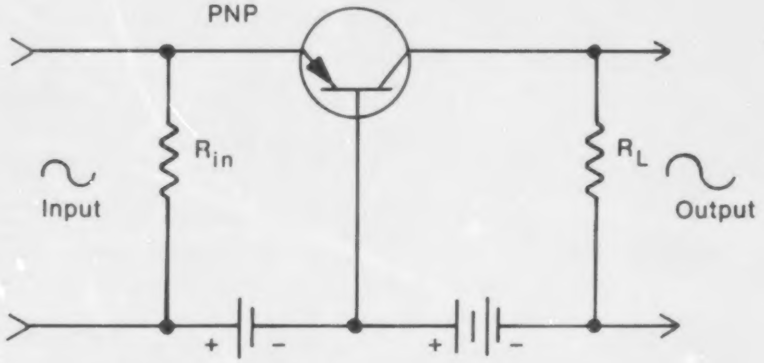
Common-collector circuit **Common-base circuit** **Common-emitter circuit**


NPN
R_{in}
R_L
Input
Output
–
+
+
–

a. ____


PNP
R_{in}
R_L
Input
Output
–
+
+
–

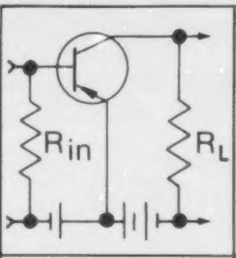
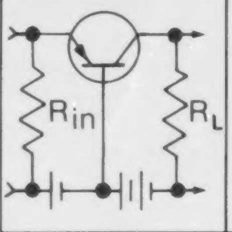
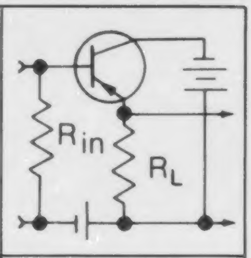
b. ____


PNP
R_{in}
R_L
Input
Output
+
–
+
–

c. ____

TEST

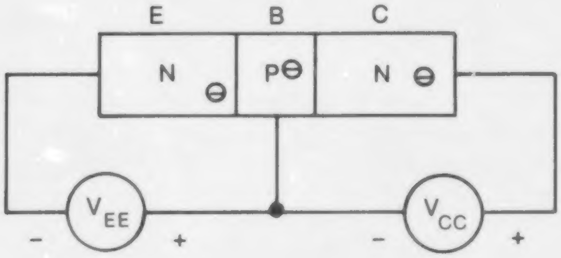
8. List characteristics of transistor circuit configurations. Complete the following chart by writing the correct characteristics in the blanks.

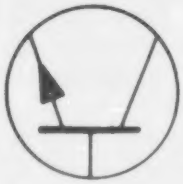
			
Characteristics	**Common Emitter**	**Common Base**	**Common Collector**
Voltage gain (A_V)	a. ______	______	______
Current gain (A_I)	b. ______	______	______
Power gain (A_P)	c. ______	______	______
Input impedance (Z)	d. ______	______	______
Output impedance (Z)	e. ______	______	______
Phase reversal	f. ______	______	______

9. Indicate the direction of current flow in the external circuits of the following transistors. Draw arrows to indicate the direction of flow.

a. npn transistors

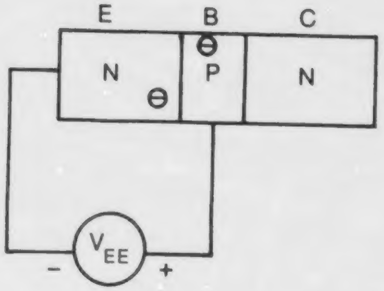
1)



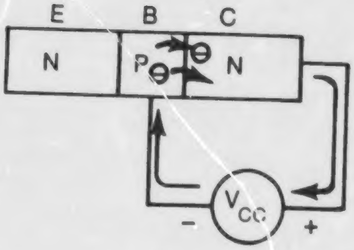


TEST

2)

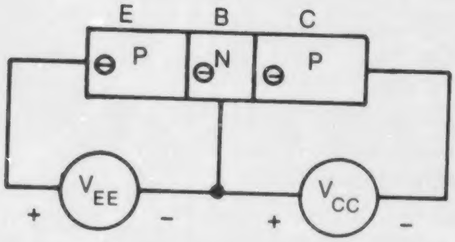


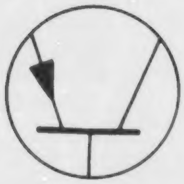
3)



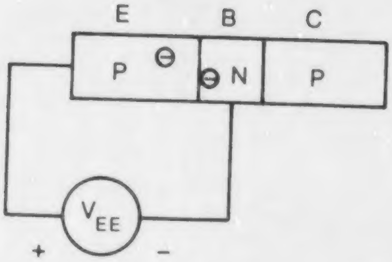
b. pnp transistors

1)

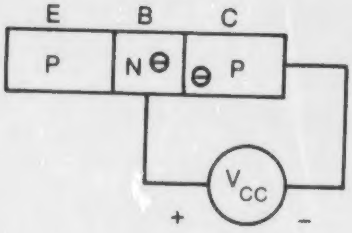

E
B
C
P
N
P
⊖
⊖
⊖
VEE
+
–
VCC
+
–



2)



3)



10. List bipolar transistor applications.

a. ______________________________

b. ______________________________

TEST

c. ______________________________

d. ______________________________

11. List bipolar transistor classifications.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

f. ______________________________

12. Calculate transistor voltage, current, and power gain for the following parameters. Show your work in the spaces provided.

a. Calculate voltage gain for a transistor having an output voltage of 12 volts with an input voltage of 5 millivolts.

A_V = ____________________

TEST

b. Calculate current gain for a transistor having an input current of 150 microamperes and an output current of 30 milliamperes.

A_I = ______________________

c. Calculate power gain for a transistor having a current gain of 50 and a voltage gain of 30.

A_P = ______________________

TEST

13. Calculate alpha and beta values for common-emitter and common-base circuits. Show your work in the spaces provided.

    a. Calculate beta gain for a common-emitter circuit where the voltage from emitter to collector is constant and collector current changes 20 milliamperes while base current changes 0.5 milliamperes.

    B = ______________________

    b. Calculate beta gain for a common-emitter circuit that has a collector current of 15 milliamperes and a base current of 0.5 milliamperes.

    B = ______________________

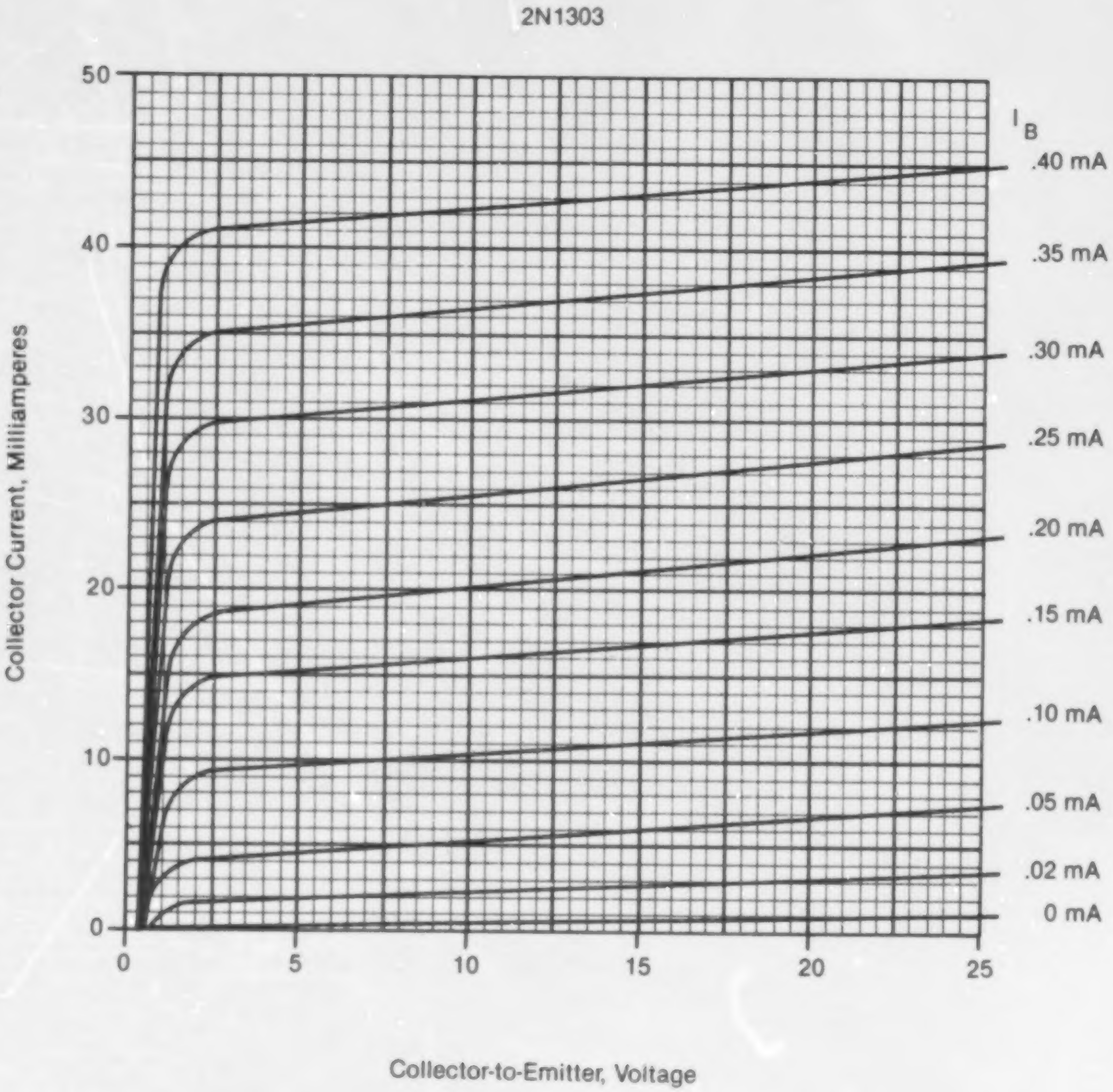
TEST

c. Calculate alpha gain for a common-base circuit where the change in collector current is 0.40 milliamperes and the corresponding change in emitter current is 0.42 milliamperes.

α = ______________________

TEST

14. Construct a transistor load line for the 2N1303 transistor depicted on the characteristic graph below. The transistor circuit has a collector-to-emitter power source of 20 volts. The collector load resistor is 800 ohms. Select a base current of 0.15 milliamperes for the quiescent point, and circle that point on the graph.



TEST

15. List transistor characteristics indicated by the arrowhead symbol.

    a. ______________________________

    b. ______________________________

    c. ______________________________

    d. ______________________________

(NOTE: Test question 16 lists the job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

16. Demonstrate the ability to

    a. Analyze the common-emitter circuit.

    b. Analyze the common-base circuit.

    c. Analyze the common-collector circuit.

    d. Make various out-of-circuit transistor checks.

    e. Use a transistor tester to check transistors.

BIPOLAR TRANSISTORS
UNIT III

ANSWERS TO TEST

1. a. 4
   b. 3
   c. 1
   d. 2
   e. 6
   f. 7
   g. 5
   h. 10
   i. 8
   j. 9
   k. 11
   l. 12
   m. 17
   n. 18
   o. 14
   p. 15
   q. 13
   r. 16

2. a. 3
   b. 5
   c. 6
   d. 2
   e. 10
   f. 4
   g. 1
   h. 7
   i. 9
   j. 8
   k. 12
   l. 16
   m. 15
   n. 11
   o. 13
   p. 14
   q. 17
   r. 18
   s. 24
   t. 21
   u. 22
   v. 19
   w. 26
   x. 25
   y. 20
   z. 23

3. a. npn transistor
   b. pnp transistor

4. a. T0-220 case
   b. T0-3 case
   c. T0-23 case
   d. T0-5 case
   e. T0-20 case

ANSWERS TO TEST

5. a. Circuit symbols
    1) pnp transistor
        a) Base
        b) Emitter
        c) Collector
    2) npn transistor
        a) Emitter
        b) Base
        c) Collector

   b. Common transistor cases
    1) T0-5 case
        a) Collector
        b) Emitter
        c) Base
    2) T0-20 case
        a) Collector
        b) Base
        c) Emitter
    3) T0-220 case
        a) Base
        b) Collector
        c) Emitter
    4) T0-23 case
        a) Base
        b) Collector
        c) Emitter

ANSWERS TO TEST

5) T0-3 case
   - a) Collector
   - b) Emitter
   - c) Base

6.

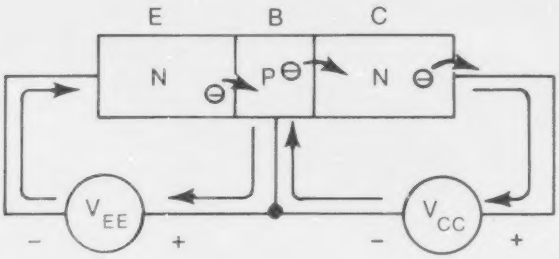
a.	E	e.	B	i.	C
b.	B	f.	E	j.	E
c.	C	g.	E	k.	B
d.	C	h.	B	l.	B

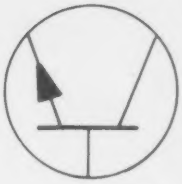
7. a. Common-collector circuit
   b. Common-emitter circuit
   c. Common-base circuit

8. a. High, high, low
   b. High, low, high
   c. Very high, medium, low
   d. Medium, low, high
   e. Medium, high, low
   f. Yes, no, no

9. a. npn transistors

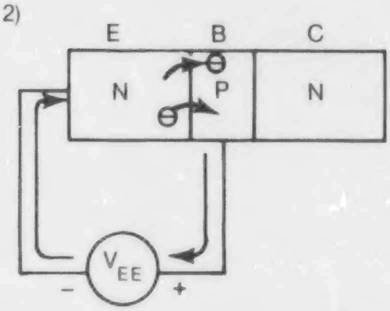
1)



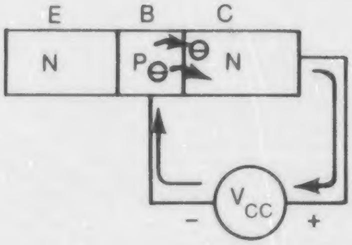


ANSWERS TO TEST

2)

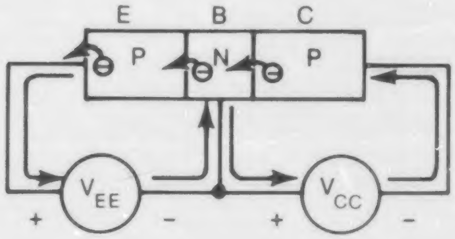


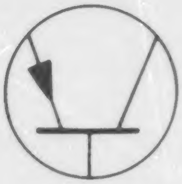
3)



b. pnp transistors

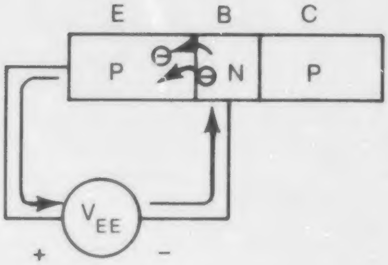
1)

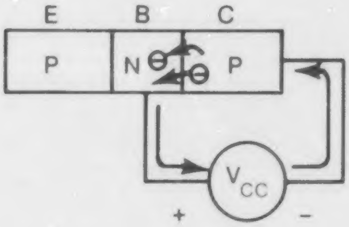

E
B
C
P
N
P
V_EE
V_CC
+
−
+
−



2)

3)





ANSWERS TO TEST

10. a. Amplifiers
    b. Oscillators
    c. Regulators
    d. Switching circuits

11. a. Polarity
    b. Material
    c. Case
    d. Power rating
    e. Part number
    f. Application

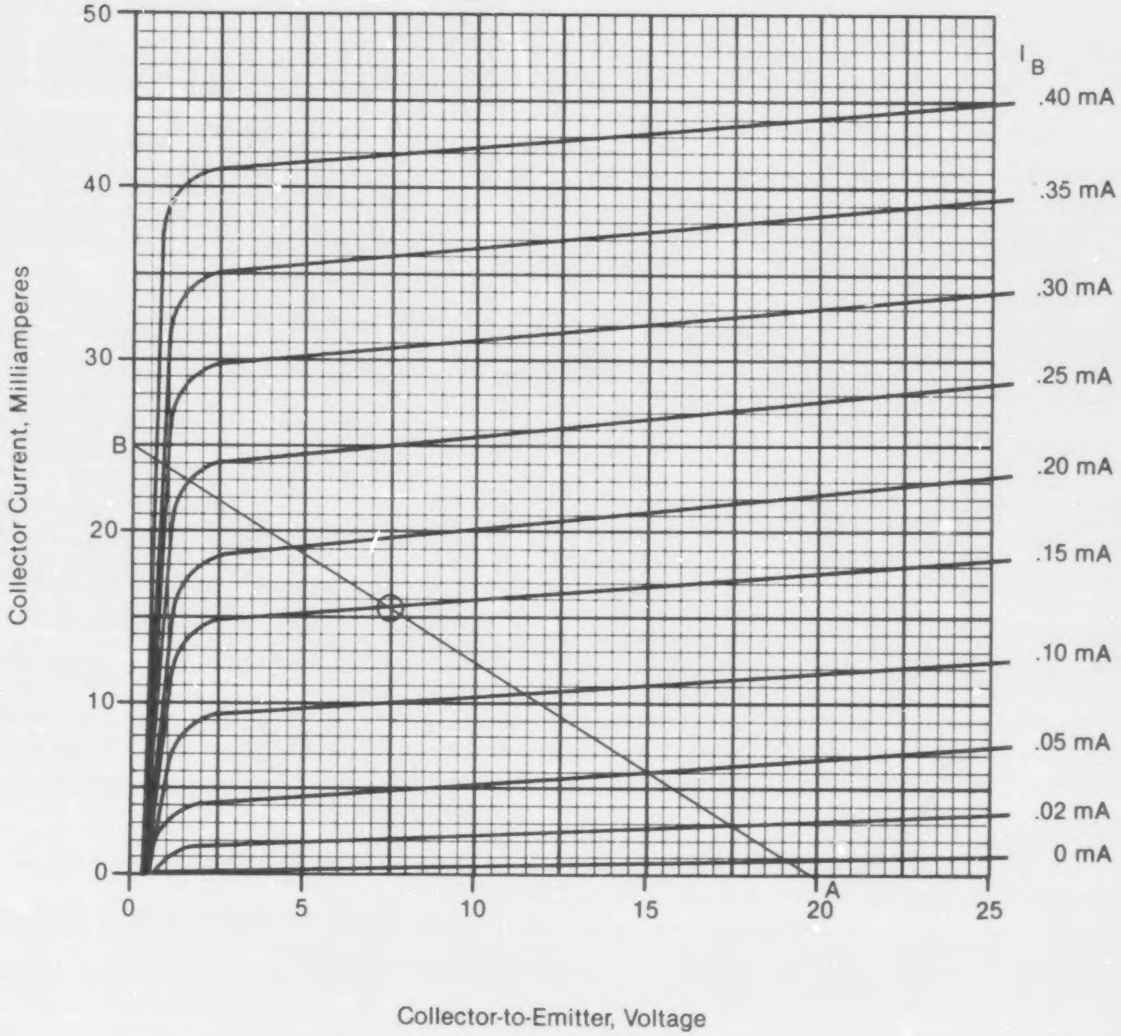
12. a. 2,400
    b. 200
    c. 1,500

13. a. 40
    b. 30
    c. 0.95

ANSWERS TO TEST

14.

2N1303



ANSWERS TO TEST

15. a. Arrowhead is always on emitter line

    b. Arrow points in direction of n-type material

    c. Current always flows against arrow

    d. Arrow (emitter) lead carries sum of base and collector currents

16. Performance skills evaluated to the satisfaction of the instructor

SPECIAL SEMICONDUCTOR DEVICES
UNIT IV

UNIT OBJECTIVE

After completing this unit, the student should be able to test special components with a transistor tester and construct circuits employing semiconductor devices. The student will show this knowledge by completing assignment sheets, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match to their correct definitions terms associated with special semiconductor devices.
2. Match to their correct interpretations abbreviations and acronyms associated with special semiconductor devices.
3. Label special semiconductor device schematic symbols.
4. Distinguish among field-effect transistor bias conditions and their effects.
5. Distinguish between characteristics of bipolar transistors and field-effect transistors.
6. Match special semiconductor devices to their correct applications.
7. Label structures of common special semiconductor devices.
8. Label schematics to show bias in common applications of field-effect transistors.
9. Demonstrate the ability to
    a. Use a transistor tester to test various special semiconductor devices.
    b. Analyze a silicon-controlled rectifier circuit.
    c. Construct and analyze a unijunction transistor oscillator circuit.
    d. Observe waveforms of a silicon-controlled rectifier circuit.

SPECIAL SEMICONDUCTOR DEVICES
UNIT IV

SUGGESTED ACTIVITIES

I. Suggested activities

   A. Make transparencies.

   B. Provide students with objective sheet.

   C. Discuss unit and specific objectives.

   D. Provide students with information, assignment, and job sheets.

   E. Discuss information and assignment sheets.

   F. Demonstrate and discuss procedures outlined in job sheets.

   G. Invite industrial maintenance person to speak to class about the use of special semiconductor devices in industry.

   H. Arrange a field trip to visit a local industry to observe equipment that utilizes solid-state electronic devices.

   I. Collect an assortment of special semiconductor devices and show to students.

   J. Make a transparency or copies of an industrial electronic circuit schematic employing special semiconductor devices. Point out the devices in the schematic.

   K. Set up an SCR control circuit, such as a light dimmer or motor speed controller; display the waveforms on an oscilloscope as the control is varied.

   L. Give test.

   M. Reteach and retest if necessary.

II. Instructional materials

   A. Objective sheet

   B. Suggested activities

   C. Information sheet

SUGGESTED ACTIVITIES

- D. Transparency masters
  1. TM #1 — FET Depletion Region
  2. TM #2 — FET Depletion Region (continued)
  3. TM #3 — FET at Pinch-Off
  4. TM #4 — Typical Special Semiconductor Devices
  5. TM #5 — Typical Special Semiconductor Devices (continued)
- E. Assignment sheets
  1. Assignment Sheet #1 — Identify Special Semiconductor Device Schematic Symbols
  2. Assignment Sheet #2 — Identify the Leads in Schematic Symbols of Special Semiconductor Devices
- F. Answers to assignment sheets
- G. Job sheets
  1. Job Sheet #1 — Use a Transistor Tester to Test Various Special Semiconductor Devices
  2. Job Sheet #2 — Analyze a Silicon-Controlled Rectifier Circuit
  3. Job Sheet #3 — Construct and Analyze a Unijunction Transistor Oscillator Circuit
  4. Job Sheet #4 — Observe Waveforms of a Silicon-Controlled Rectifier Circuit
- H. Test
- I. Answers to test

III. Unit references

A. Alley, Charles L., and Kenneth W. Atwood. *Electronic Engineering*, 3rd ed. New York: John Wiley and Sons, 1973.

B. Chirlian, Paul M. *Electronic Circuits: Physical Principles, Analysis, and Design*. New York: McGraw-Hill Book Company, 1971.

C. *Graphic Symbols for Electrical and Electronics Diagrams*. New York: Institute of Electrical and Electronics Engineers, 1981.

SPECIAL SEMICONDUCTOR DEVICES
UNIT IV

INFORMATION SHEET

I. Terms and definitions

- A. Source — Electrode of a field-effect transistor corresponding to the emitter of a bipolar transistor
- B. Drain — Electrode of a field-effect transistor corresponding to the collector of a bipolar transistor
- C. Gate — Electrode of various semiconductor devices that provides control for operation
- D. Channel — Narrow path within a field-effect transistor through which conduction of current is controlled
- E. Field effect — Electromagnetic force that controls conduction in field-effect transistors
- F. Substrate — Base material upon or within which semiconductor devices are constructed

  (NOTE: Substrate may also be called *bulk*. Usually one terminal is connected to this material, allowing the terminal to help dissipate heat and also to drain static charges. The substrate may be an insulator or a semiconductor.)
- G. Pinch-off voltage — Voltage from the gate to the source of field-effect transistors at which conduction of current ceases
- H. Depletion region — Area within semiconductor material where charge carriers are neutralized and current cannot flow
- I. Depletion mode — Field-effect transistor operation in which a negative voltage on the gate repels electrons in the channel and reduces conduction
- J. Enhancement mode — Field-effect transistor operation in which a positive voltage on the gate attracts electrons into the channel and increases conduction
- K. Breakover voltage — Voltage level at which a diode device will switch on and conduct current
- L. Input impedance — Measure of the restriction to current at the input of a device
- M. Trigger — Electrical impulse used to turn devices on and off

INFORMATION SHEET

II. Abbreviations and acronyms associated with special semiconductor devices

A. FET — Field-effect transistor

B. JFET — Junction field-effect transistor

C. MOSFET — Metal-oxide semiconductor field-effect transistor

D. SCR - Silicon-controlled rectifier

E. UJT — Unijunction transistor

F. IGFET — Insulated-gate field-effect transistor

G. LASCR — Light-activated silicon-controlled rectifier

H. SCS — Silicon-controlled switch

I. SUS — Silicon unilateral switch

J. DGFET — Dual-gate field-effect transistor

K. S — Source lead

L. D — Drain lead

M. G — Gate lead

N. U — Substrate lead

O. B — Base lead

P. K — Cathode lead; multiplier of 1,000

Q. A — Anode lead

R. E — Emitter lead

S. P — p-material

T. N — n-material

U. V_{GS} — Gate source voltage

V. V_{DS} — Drain source voltage

W. V_{GSP} — Gate source voltage at pinch-off

X. V_{DD} — Drain supply voltage

INFORMATION SHEET

Y. R_D — Load resistor in drain circuit of field-effect transistor circuit

Z. R_G — Bias resistor connected to gate in field-effect transistor circuit

AA. R_S — Source resistor in field-effect transistor circuit

BB. C — Capacitor

III. Special semiconductor device schematic symbols (Figures 1-22; Assignment Sheets #1 and #2)

A. n-channel FET

(NOTE: The n-channel symbol may be remembered by the arrowhead pointing "iN." The arrowhead depicted closer to one lead identifies that lead as the source terminal.)

FIGURE 1

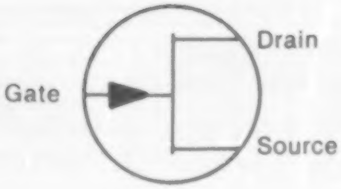
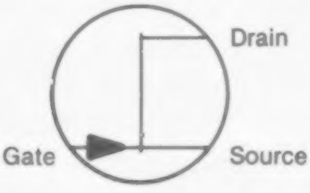

Drain
Gate
Source

FIGURE 2


Drain
Gate
Source

B. p-channel FET

FIGURE 3

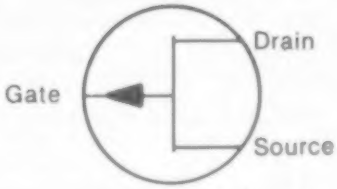
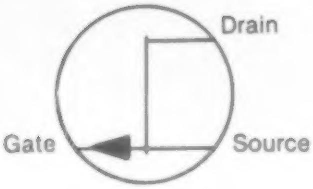

Drain
Gate
Source

FIGURE 4


Drain
Gate
Source

INFORMATION SHEET

C. n-channel MOSFET

(NOTE: MOSFETs have insulation between the gate and the channel. This is depicted by the gap in the following schematic symbols.)

1. Depletion mode

FIGURE 5

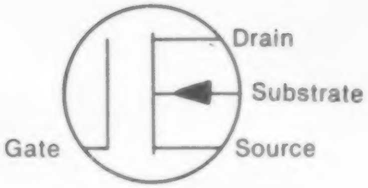
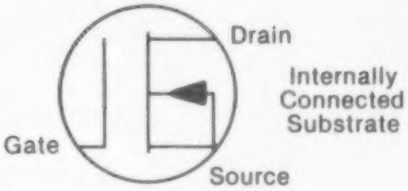
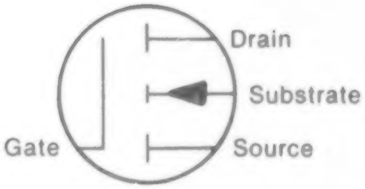

Drain
Substrate
Gate
Source

FIGURE 6


Drain
Internally Connected Substrate
Gate
Source

2. Enhancement mode

FIGURE 7


Drain
Substrate
Gate
Source

INFORMATION SHEET

D. p-channel MOSFET

1. Depletion mode

FIGURE 8

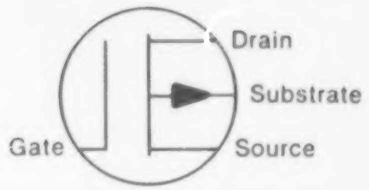
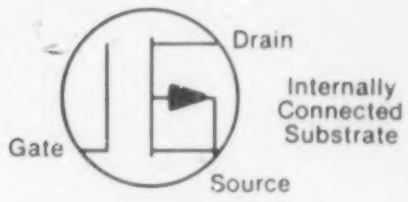
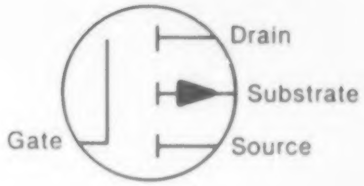

Drain
Substrate
Gate
Source

FIGURE 9


Drain
Internally
Connected
Substrate
Gate
Source

2. Enhancement mode

FIGURE 10


Drain
Substrate
Gate
Source

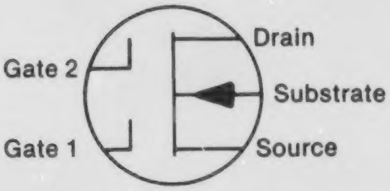
INFORMATION SHEET

E. Dual-gate MOSFET

1. n-channel

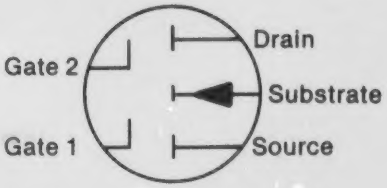
a. Depletion mode

FIGURE 11


Drain
Gate 2
Substrate
Gate 1
Source

b. Enhancement mode

FIGURE 12

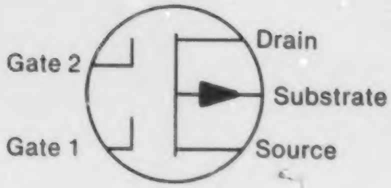

Drain
Gate 2
Substrate
Gate 1
Source

INFORMATION SHEET

2. p-channel

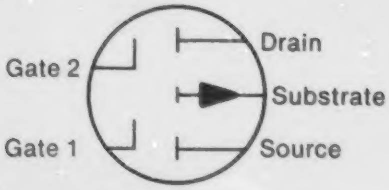
a. Depletion mode

FIGURE 13


Drain
Gate 2
Substrate
Gate 1
Source

b. Enhancement mode

FIGURE 14

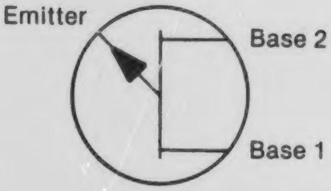

Drain
Gate 2
Substrate
Gate 1
Source

INFORMATION SHEET

F. Unijunction transistor (UJT)

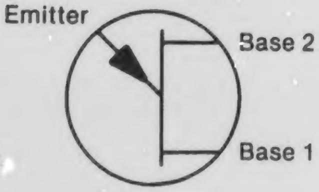
1. p-type base

FIGURE 15


Emitter
Base 2
Base 1

2. n-type base

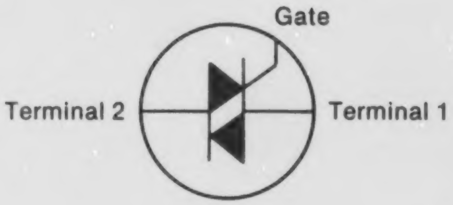
FIGURE 16


Emitter
Base 2
Base 1

INFORMATION SHEET

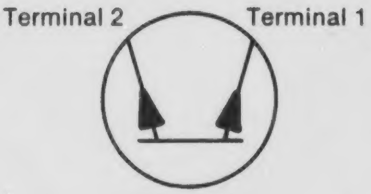
G. Triac

FIGURE 17


Gate
Terminal 2
Terminal 1

H. Diac

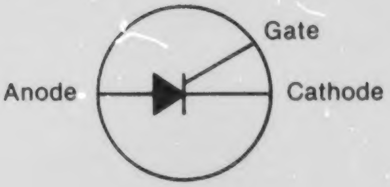
FIGURE 18


Terminal 2
Terminal 1

INFORMATION SHEET

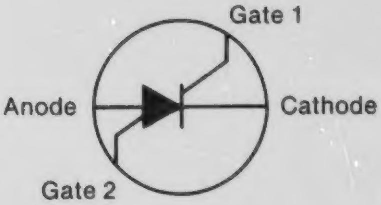
I. Silicon-controlled rectifier (SCR)

FIGURE 19


Gate
Anode
Cathode

J. Silicon-controlled switch (SCS)

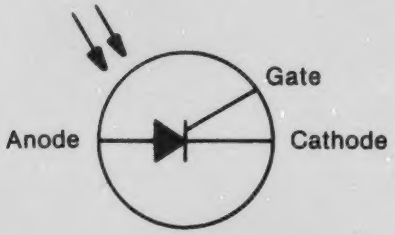
FIGURE 20


Gate 1
Anode
Cathode
Gate 2

INFORMATION SHEET

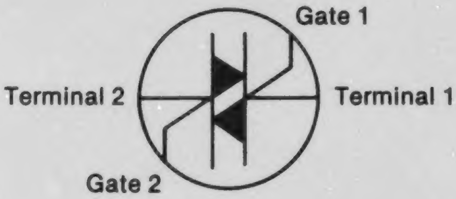
K. Light-activated silicon-controlled rectifier (LASCR)

FIGURE 21


Gate
Anode
Cathode

L. Silicon unilateral switch (SUS)

FIGURE 22


Gate 1
Terminal 2
Terminal 1
Gate 2

IV. Field-effect transistor bias conditions and their effects

A. No bias (Transparency #1)

1. Depletion region is narrow
2. Channel is wide

B. V_{DS} equals positive and V_{GS} equals negative but less than V_{GSP} (Transparency #2)

1. Depletion region is controlled by V_{GS}
2. Channel width varies according to V_{GS}
3. Conduction varies according to V_{GS}

INFORMATION SHEET

C. V_{DS} equals positive and V_{GS} equals negative at V_{GSP} (Transparency #3)

  1. Depletion region is wide enough to close the channel

  2. No conduction takes place

V. Characteristics of bipolar and field-effect transistors

  A. Bipolar transistors

    1. Are current-controlled devices

    2. Have higher frequency response

    3. Have higher power ratings

  B. Field-effect transistors

    1. Are voltage-controlled devices

    2. Have higher input impedance

    3. Produce less noise

    4. Are less sensitive to heat

    5. Are able to operate at higher voltage

    6. Are less sensitive to radiation

    7. Are more sensitive to static

VI. Special semiconductor devices and their applications (Transparencies #4 and #5)

  A. FET — Serves as high-input impedance device for amplifying input voltage variations applied to gate; used as amplifier

  B. UJT — Switches on and off according to voltages and bias applied; used as oscillator or pulse generator

  C. SCR — Rectifies AC to DC according to timing of electrical impulse to gate lead; used as controllable rectifier and frequently as a switch

  D. Diac — Switches on in either direction when voltage levels reach breakover voltage; used to provide triggering to AC control circuits

  E. Triac — Switches on in either direction when gate is triggered; used to vary AC power

INFORMATION SHEET

F. SCS — Switches on or off by triggering either of two gates, but conducts current in only one direction; used as variable output rectifier or as DC electronic switch

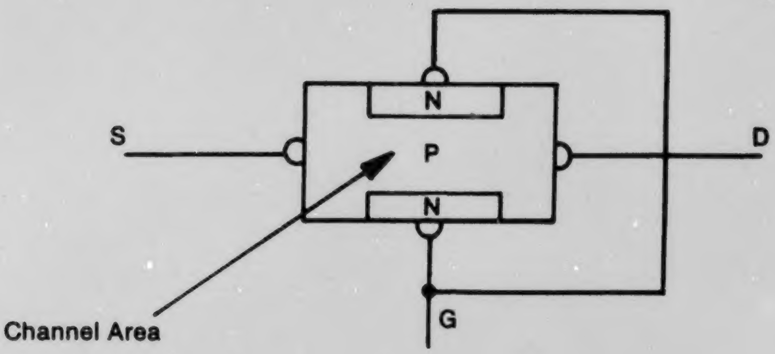
G. LASCR — Switches on according to gate potential and intensity of light; used to control outdoor lighting circuits and other light-affected processes

H. SUS -- Switches on or off in either direction as controlled by two gates; used as AC power controller or AC electronic switch

VII. Structures of common special semiconductor devices (Figures 23-28)

A. p-channel FET

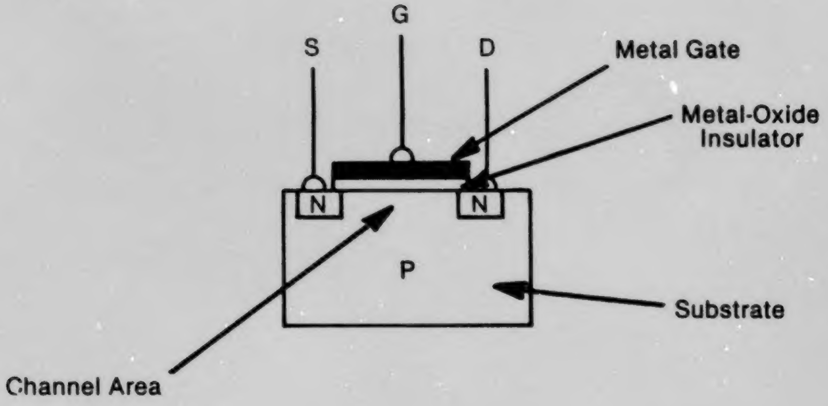
FIGURE 23



INFORMATION SHEET

B. p-channel MOSFET

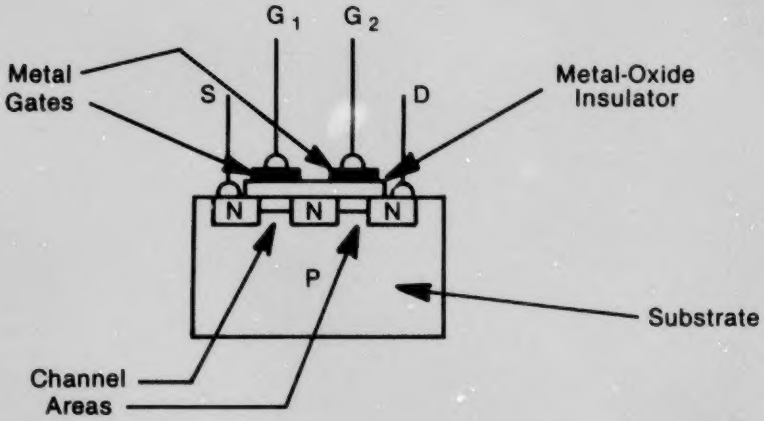
FIGURE 24


G
S
D
Metal Gate
Metal-Oxide Insulator
N
N
P
Substrate
Channel Area

C. p-channel DGFET

(NOTE: Dual-gate FETs are always MOSFET types. The metal oxide acts as the insulator. This insulation provides for extremely high input impedance.)

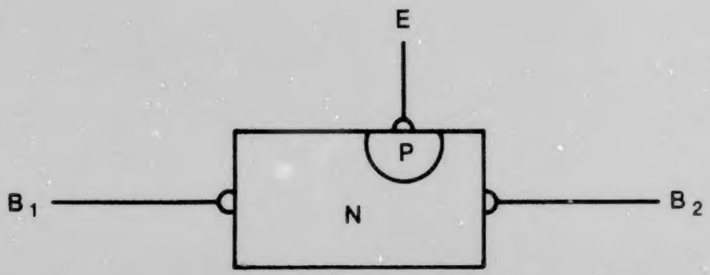
FIGURE 25


G_1
G_2
Metal Gates
S
D
Metal-Oxide Insulator
N
N
N
P
Substrate
Channel Areas

INFORMATION SHEET

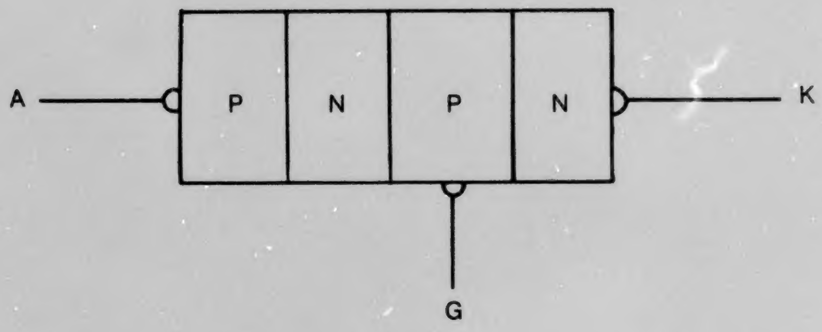
D. UJT

FIGURE 26



E. SCR

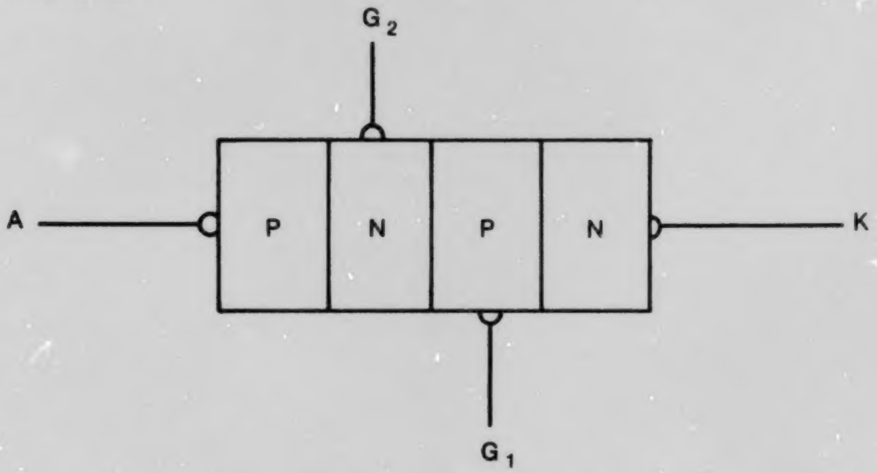
FIGURE 27



INFORMATION SHEET

F. SCS

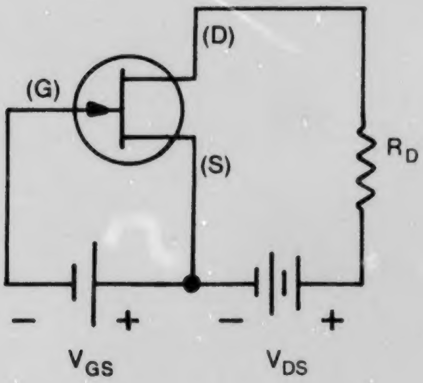
FIGURE 28


G 2
A
P
N
P
N
K
G 1

VIII. Bias in common applications of field-effect transistors (Figures 29-31)

A. Junction device n-channel FET

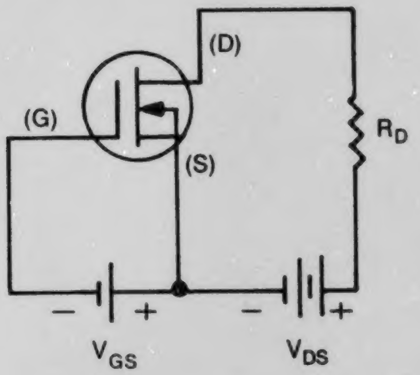
FIGURE 29


(D)
(G)
(S)
R D
−
+
−
+
V GS
V DS

INFORMATION SHEET

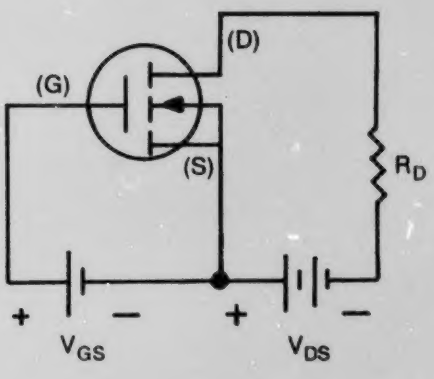
B. MOSFET, depletion mode

FIGURE 30

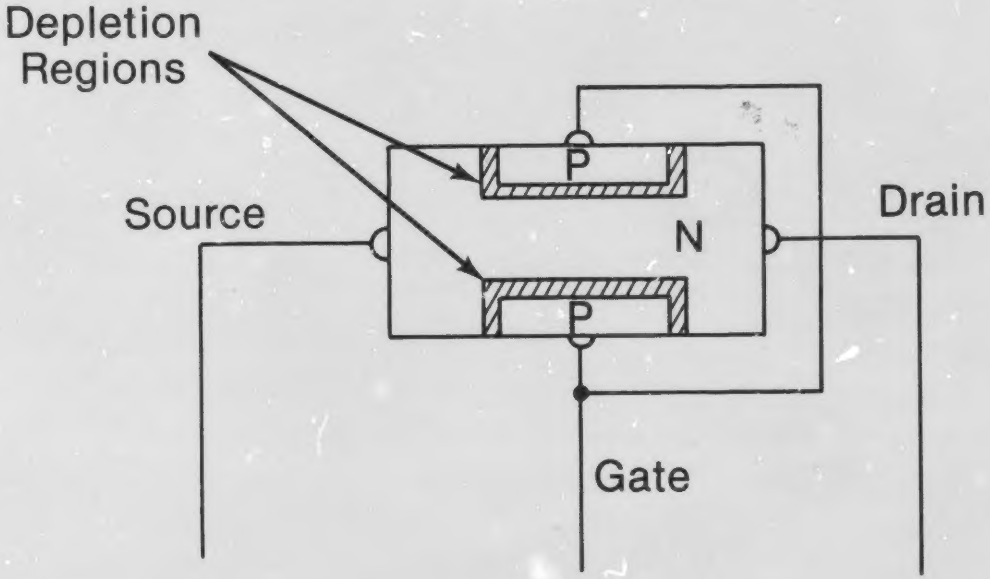

(D)
(G)
(S)
R_D
− +
V_{GS}
− +
V_{DS}

C. MOSFET, enhancement mode

FIGURE 31


(D)
(G)
(S)
R_D
+ −
V_{GS}
+ −
V_{DS}

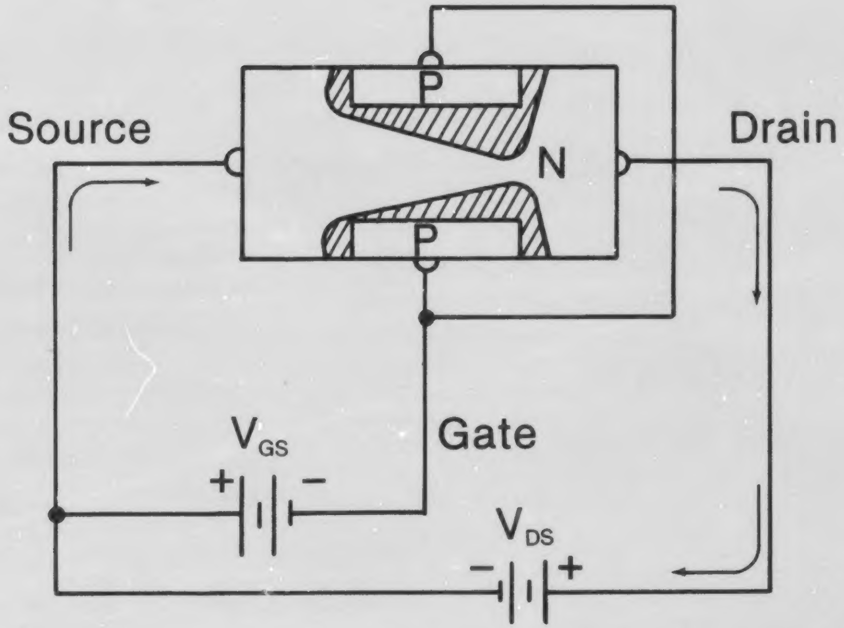
FET Depletion Region


Depletion Regions
Source
Drain
P
N
P
Gate

No Bias Applied

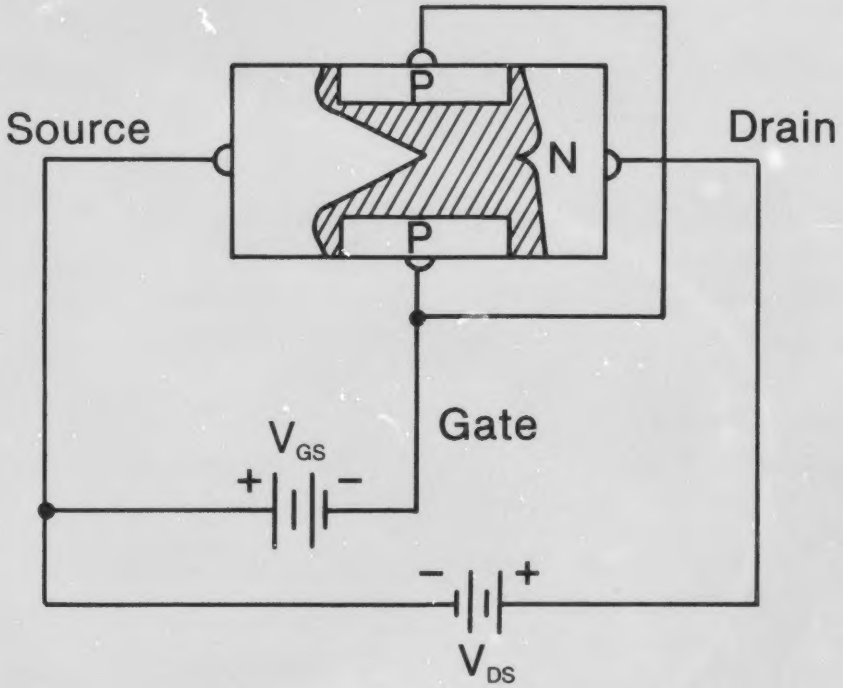
FET Depletion Region

(Continued)


P
Source
N
Drain
P
V_{GS}
Gate
+
−
V_{DS}
−
+

V_{DS} = Positive, V_{GS} = Negative but Less Than V_{GSP}

FET at Pinch-Off

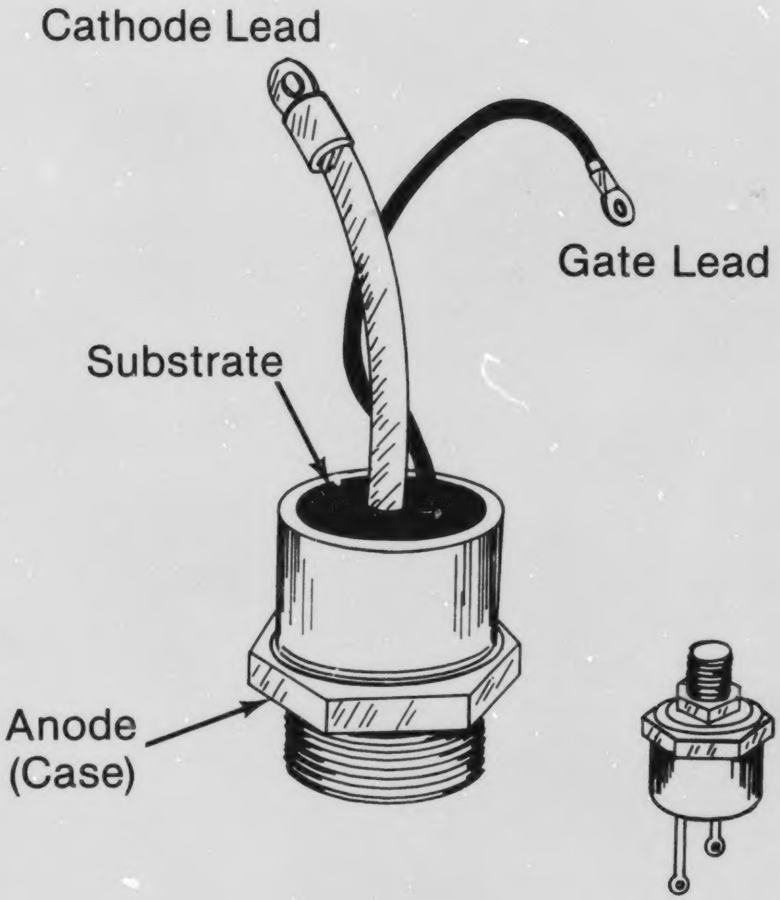

Source
Drain
P
N
P
Gate
V_{GS}
+
−
−
+
V_{DS}

V_{DS} = Positive, V_{GS} = Negative at V_{GSP}

TM #3

GIE - 231-A

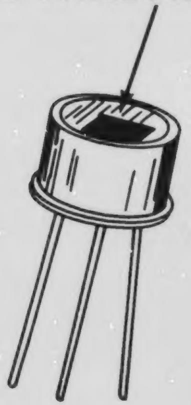
Typical Special Semiconductor Devices


Cathode Lead
Gate Lead
Substrate
Anode
(Case)

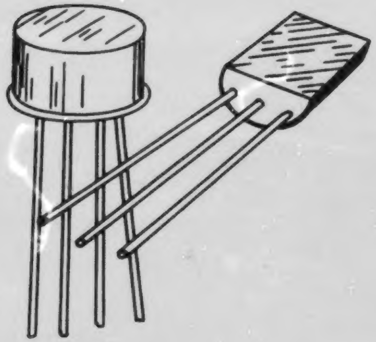
Typical SCR or TRIAC

Typical Special Semiconductor Devices

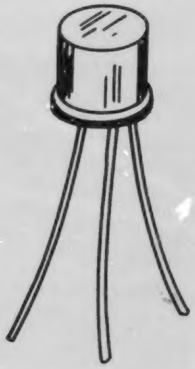
(Continued)



Typical LASCR



Typical FETs



Typical UJT

Solid-state devices cannot be distinguished by the cases. Bipolar transistors, UJTs, FETs, and SCRs are often encapsulated in identical cases.

SPECIAL SEMICONDUCTOR DEVICES
UNIT IV

ASSIGNMENT SHEET #1 — IDENTIFY SPECIAL SEMICONDUCTOR DEVICE SCHEMATIC SYMBOLS

NAME ______________________________ SCORE ______________

The electronics technician must be able to recognize schematic symbols of special semiconductor devices in order to test, calibrate, or troubleshoot electronic circuits employed in industry. There are many such devices and not all are covered in this unit. Those depicted below are identified in this unit and are common to industry.

Identify the following devices by writing the correct names in the spaces provided.

n-channel FET

p-channel FET

n-channel MOSFET, depletion mode

n-channel MOSFET, enhancement mode

p-channel MOSFET, depletion mode

p-channel MOSFET, enhancement mode

n-channel dual-gate MOSFET, depletion mode

n-channel dual-gate MOSFET, enhancement mode

p-channel dual-gate MOSFET, depletion mode

p-channel dual-gate MOSFET, enhancement mode

Unijunction transistor (UJT), p-type base

Unijunction transistor (UJT), n-type base

Triac

Diac

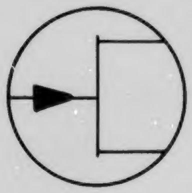
Silicon-controlled rectifier (SCR)

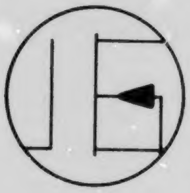
Silicon-controlled switch (SCS)

Light-activated silicon-controlled rectifier (LASCR)

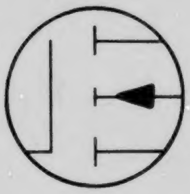
Silicon unilateral switch (SUS)

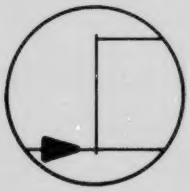
ASSIGNMENT SHEET #1



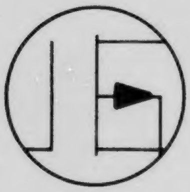


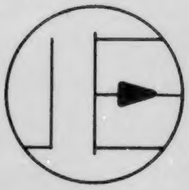
A. ______________________________ B. ______________________________



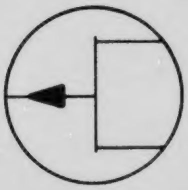


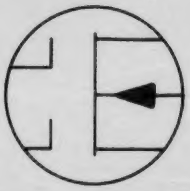
C. ______________________________ D. ______________________________





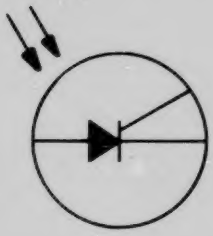
E. ______________________________ F. ______________________________





G. ______________________________ H. ______________________________

ASSIGNMENT SHEET #1



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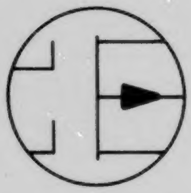

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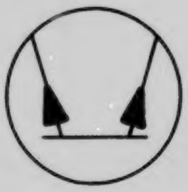

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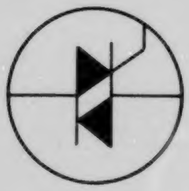
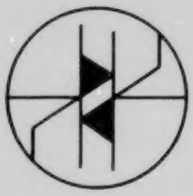


L. ______________________________



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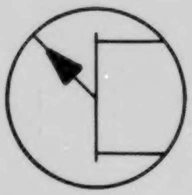

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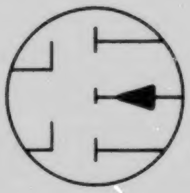
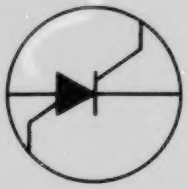
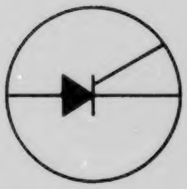


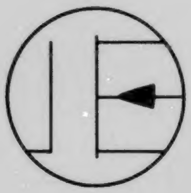
O. ______________________________



P. ______________________________

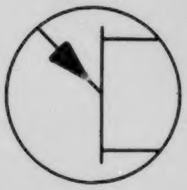
ASSIGNMENT SHEET #1

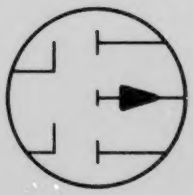




Q. ______________________________

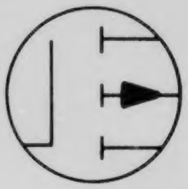
R. ______________________________

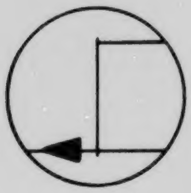




S. ______________________________

T. ______________________________





U. ______________________________

V. ______________________________

SPECIAL SEMICONDUCTOR DEVICES
UNIT IV

ASSIGNMENT SHEET #2 — IDENTIFY THE LEADS IN SCHEMATIC SYMBOLS OF SPECIAL SEMICONDUCTOR DEVICES

NAME ____ SCORE ______________

To be able to troubleshoot effectively and replace special semiconductor devices, industrial electronics technicians must be able to recognize semiconductor leads.

Identify the leads in the following schematic symbols. Write the correct abbreviations in the spaces provided.

G — Gate

D — Drain

S — Source

U — Substrate

G1 — Gate 1

G2 — Gate 2

E — Emitter

B1 — Base 1

B2 — Base 2

T1 — Terminal 1

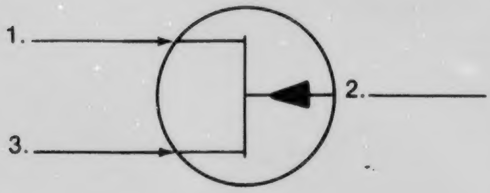
T2 — Terminal 2

A — Anode

K — Cathode

T — Terminal

A.



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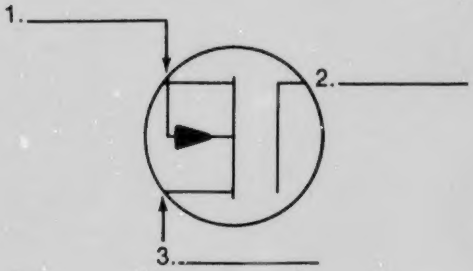

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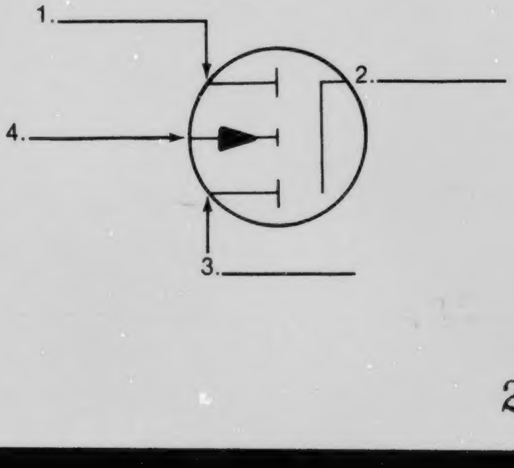
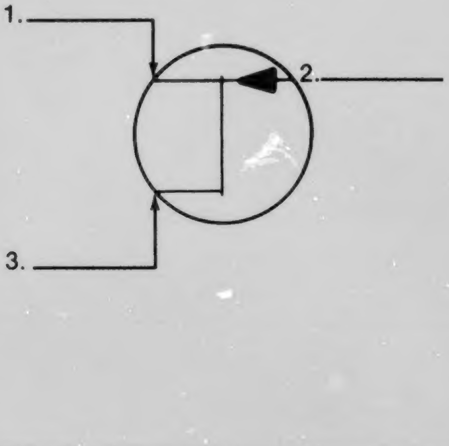
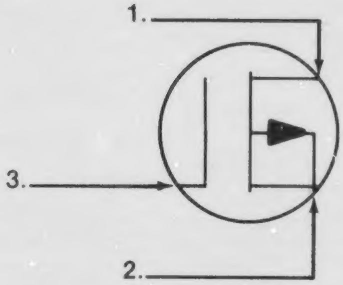


D.

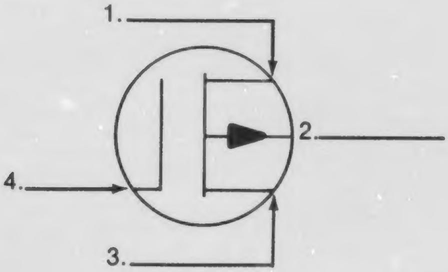


ASSIGNMENT SHEET #2

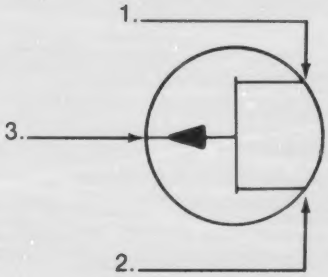
E.



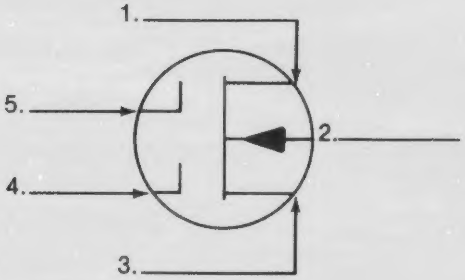
F.



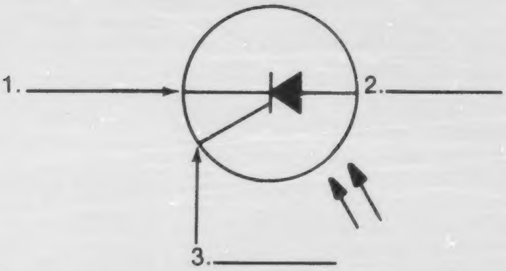
G.



H.



I.



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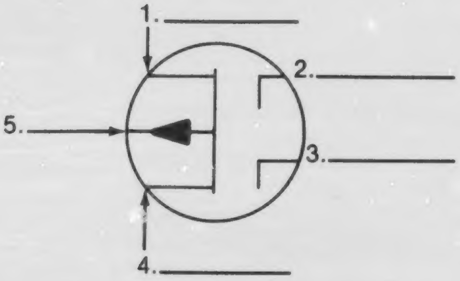

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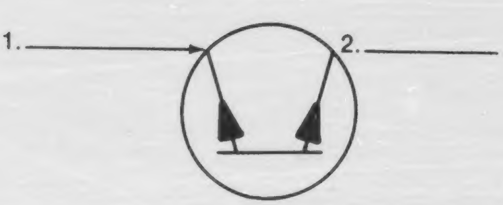
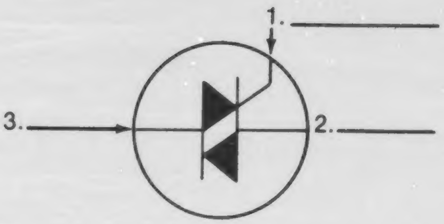
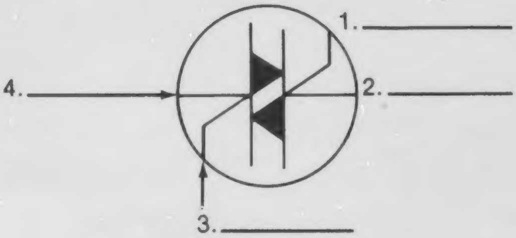


L.



ASSIGNMENT SHEET #2

M.



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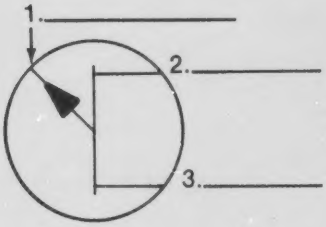
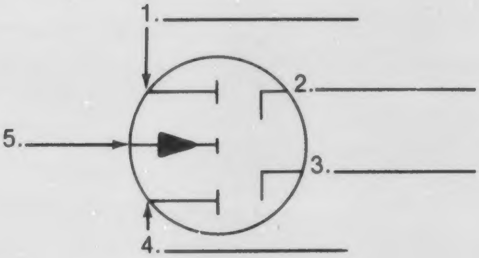


O.



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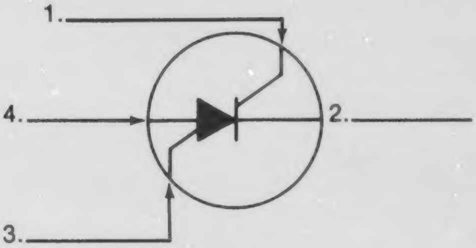

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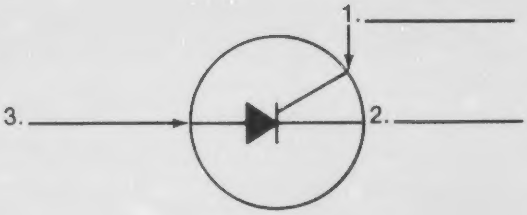

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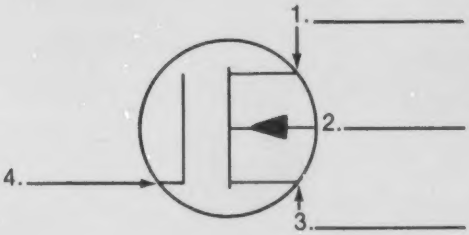

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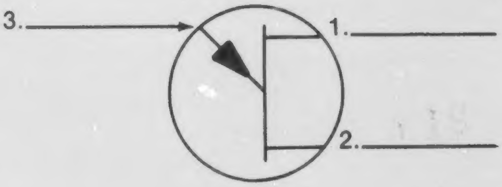

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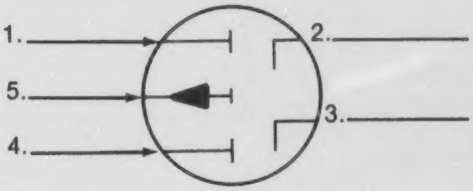
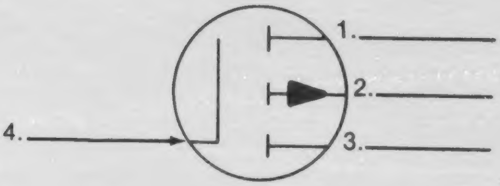


ASSIGNMENT SHEET #2

U.



SPECIAL SEMICONDUCTOR DEVICES
UNIT IV

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

A. n-channel FET

B. n-channel MOSFET, depletion mode

C. n-channel MOSFET, enhancement mode

D. n-channel FET

E. p-channel MOSFET, depletion mode

F. p-channel MOSFET, depletion mode

G. p-channel FET

H. n-channel dual-gate MOSFET, depletion mode

I. Light-activated silicon-controlled rectifier (LASCR)

J. p-channel dual-gate MOSFET, depletion mode

K. Diac

L. Triac

M. Silicon unilateral switch (SUS)

N. Unijunction transistor (UJT), p-type base

O. n-channel dual-gate MOSFET, enhancement mode

P. Silicon-controlled switch (SCS)

Q. Silicon-controlled rectifier (SCR)

R. n-channel MOSFET, depletion mode

S. Unijunction transistor (UJT), n-type base

T. p-channel dual-gate MOSFET, enhancement mode

U. p-channel MOSFET, enhancement mode

V. p-channel FET

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #2

(NOTE: If not discernable, certain leads could be transposed as in A and throughout this assignment sheet and be correct. Answers are given for either unless the symbol shows one lead differentiated from the other. The drain, however, is nearest Gate 2 and the source nearest Gate 1.)

A. 1. D or 1. S
2. G 2. G
3. S 3. D

B. 1. S
2. G
3. D

C. 1. S or 1. D
2. G 2. G
3. D 3. S
4. U 4. U

D. 1. S
2. G
3. D

E. 1. D
2. S
3. G

F. 1. D or 1. S
2. U 2. U
3. S 3. D
4. G 4. G

ANSWERS TO ASSIGNMENT SHEETS

G. 1. D or 1. S
2. S 2. D
3. G 3. G

H. 1. D or 1. S
2. U 2. U
3. S 3. D
4. G1 4. G2
5. G2 5. G1

I. 1. K
2. A
3. G

J. 1. D or 1. S
2. G2 2. G1
3. G1 3. G2
4. S 4. D
5. U 5. U

K. 1. T2
2. T1

L. 1. G
2. T1
3. T2

ANSWERS TO ASSIGNMENT SHEETS

M.	1.	G1	or	1.	G2
	2.	T1		2.	T2
	3.	G2		3.	G1
	4.	T2		4.	T1
N.	1.	E			
	2.	B2			
	3.	B1			
O.	1.	D	or	1.	S
	2.	G2		2.	G1
	3.	G1		3.	G2
	4.	S		4.	D
	5.	U		5.	U
P.	1.	G1			
	2.	K			
	3.	G2			
	4.	A			
Q.	1.	G			
	2.	K			
	3.	A			
R.	1.	D	or	1.	S
	2.	U		2.	U
	3.	S		3.	D
	4.	G		4.	G

ANSWERS TO ASSIGNMENT SHEETS

S.	1.	B2			
	2.	B1			
	3.	E			
T.	1.	D	or	1.	S
	2.	G2		2.	G1
	3.	G1		3.	G2
	4.	S		4.	D
	5.	U		5.	U
U.	1.	D	or	1.	S
	2.	U		2.	U
	3.	S		3.	D
	4.	G		4.	G

SPECIAL SEMICONDUCTOR DEVICES
UNIT IV

JOB SHEET #1 — USE A TRANSISTOR TESTER TO TEST VARIOUS SPECIAL SEMICONDUCTOR DEVICES

I. Equipment and materials

A. Transistor tester

B. Field-effect and Darlington transistors

C. Appropriate operator's manuals

II. Procedure

A. Set up transistor tester for use

B. Test a FET, using the operator's manual or the instructor's explanation of testing procedure

C. Explain results below

____

____

____

D. Test a Darlington transistor

E. Explain results below

____

____

____

(NOTE: Discuss your results with the instructor.)

F. Put away materials and equipment

SPECIAL SEMICONDUCTOR DEVICES
UNIT IV

JOB SHEET #2 — ANALYZE A SILICON-CONTROLLED RECTIFIER CIRCUIT

I. Equipment and materials

A. SCR, C106B or equivalent

B. DC power supply

C. Lamp, #47 or equivalent

D. Potentiometer, 10 kohm

E. Resistor, 220 ohm

F. Resistor 560 ohm

G. Multimeter

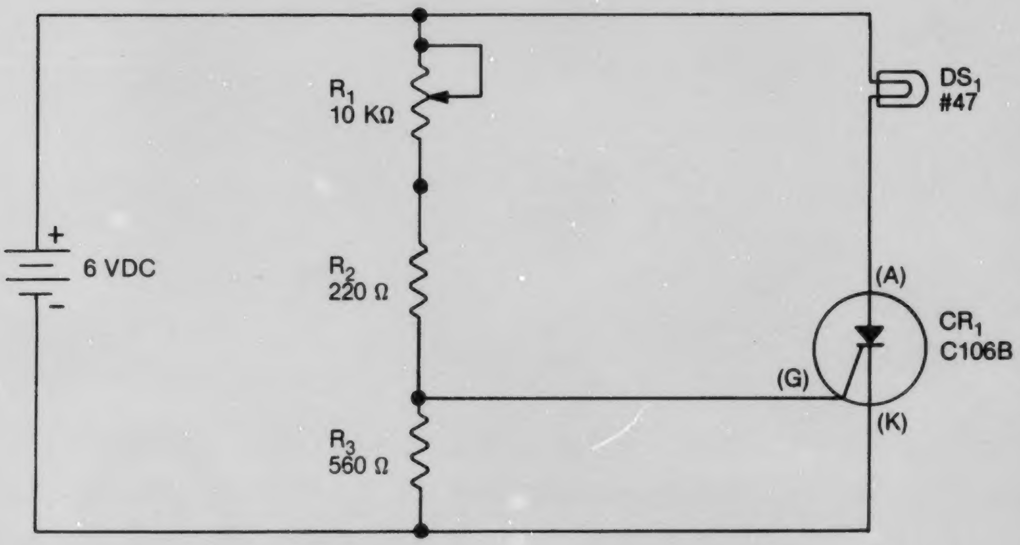
H. Test leads

I. Breadboard

II. Procedure

A. Construct circuit as shown in Figure 32

FIGURE 32


R1
10 KΩ
DS1
#47
+
6 VDC
-
R2
220 Ω
(A)
CR1
C106B
(G)
(K)
R3
560 Ω

JOB SHEET #2

B. Adjust 10-kohm potentiometer for maximum resistance

(NOTE: Have instructor check circuit before proceeding.)

C. Turn on power supply and adjust for 6 volts

D. Connect voltmeter between gate and cathode leads of SCR

E. Decrease resistance of potentiometer slowly until lamp lights; record voltage reading below

Voltage = ____________________

F. Disconnect gate lead and observe results

Gate disconnect = ____________________

G. Replace gate lead

H. Return potentiometer to maximum resistance position

I. Place a short between the anode and cathode of the SCR; record results below

(NOTE: When the short is removed, the lamp should go out.)

Anode to cathode short = ____________________

J. Repeat steps E through I; compare the results with those obtained the first time

Voltage = ____________________

Gate disconnect = ____________________

Anode to cathode short = ____________________

K. Decrease resistance of potentiometer slowly until lamp lights; record voltage reading below

Voltage = ____________________

L. Return potentiometer to maximum resistance position

M. Turn off power supply and then turn it on again; record results below

(NOTE: The lamp should go out and not come back on.)

Power off to on = ____________________

JOB SHEET #2

N. Explain whether the gate voltage was approximately the same each time the SCR triggered, and whether it was the same when the lamp came on

O. Explain the effect on the circuit operation of removing the gate lead

(NOTE: Discuss your results with the instructor.)

P. Clean work area; put away materials and equipment

SPECIAL SEMICONDUCTOR DEVICES
UNIT IV

JOB SHEET #3 — CONSTRUCT AND ANALYZE A UNIJUNCTION TRANSISTOR OSCILLATOR CIRCUIT

I. Equipment and materials

A. Unijunction transistor, 2N492 or equivalent

B. Potentiometer, 20 kohm

C. Capacitor, 0.01 microfarad

D. Capacitor, 0.1 microfarad

E. Resistor, 47 ohm

F. Variable DC power supply with leads, capable of 10 to 16 volts

G. Breadboard

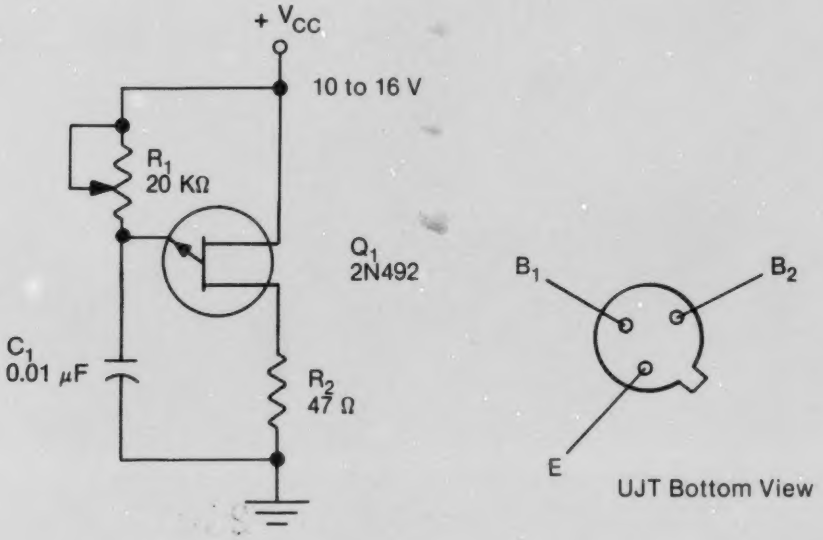
H. Dual-trace oscilloscope with probes

I. Ohmmeter with test leads

II. Procedure

A. Construct the circuit as shown in Figure 33, using the 0.01 microfarad capacitor; do not connect power supply at this time

FIGURE 33



JOB SHEET #3

B. Adjust 20-kohm potentiometer for 10 kohms resistance

C. Adjust power supply for 10 volts; turn it off

(NOTE: Have instructor check your circuit and adjustments before proceeding.)

D. Connect the power supply; turn it on

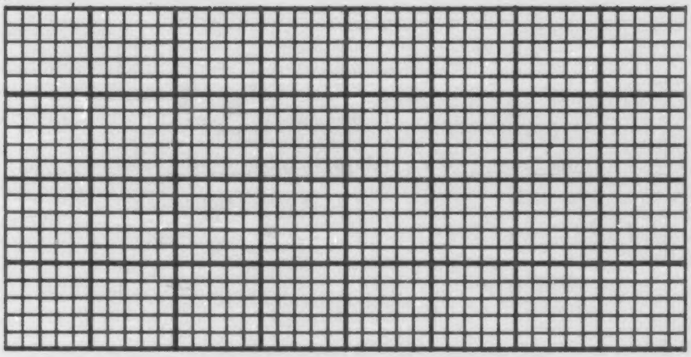
E. Check all three UJT leads with oscilloscope; sketch observed waveforms on graphs provided below and on the following page

EMITTER WAVEFORM

BASE 1 WAVEFORM

JOB SHEET #3

BASE 2 WAVEFORM



F. Measure frequency, using the oscilloscope; record below

Frequency = ____________________

G. Vary potentiometer while observing waveform at emitter lead on oscilloscope

H. Describe briefly the effect of varying the potentiometer

____

____

I. Change the capacitor to 0.1 microfarad

J. Measure the frequency; record

Frequency = ____________________

(NOTE: Discuss your results with the instructor.)

K. Clean work area; put away equipment and materials

SPECIAL SEMICONDUCTOR DEVICES
UNIT IV

JOB SHEET #4 — OBSERVE WAVEFORMS OF A SILICON-CONTROLLED RECTIFIER CIRCUIT

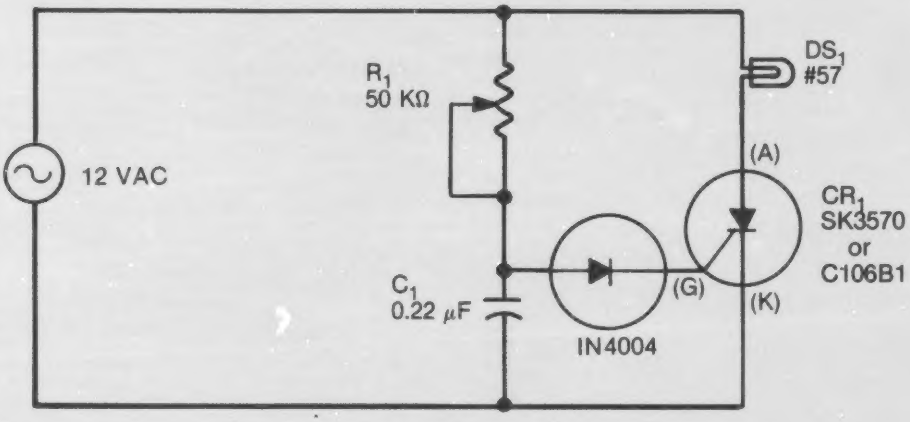
I. Equipment and materials

- A. Dual-trace oscilloscope with probes
- B. Sine-wave generator, 12 volts rms output
- C. Potentiometer, 50 kohm
- D. Capacitor, 0.22 microfarad
- E. SCR, type SK3570, C106B1, or any small-powered SCR
- F. Diode, type IN4004
- G. Lamp, 12-volt, #57 or equivalent
- H. Breadboard

II. Procedure

- A. Construct the circuit as shown in Figure 34, but do not connect the sine-wave generator

FIGURE 34



- B. Adjust output for 12 volts AC rms with sine-wave generator disconnected

  (NOTE: If you use the oscilloscope to measure the amplitude of the AC sine wave, remember that the peak-to-peak value will be 2.82 times the rms value.)

JOB SHEET #4

C. Adjust the potentiometer to approximately midrange

(NOTE: Ask your instructor to check your circuit.)

D. Turn off sine-wave generator; connect it to circuit and turn it on

(NOTE: The lamp should glow.)

E. Adjust potentiometer slowly and observe any change in lamp intensity

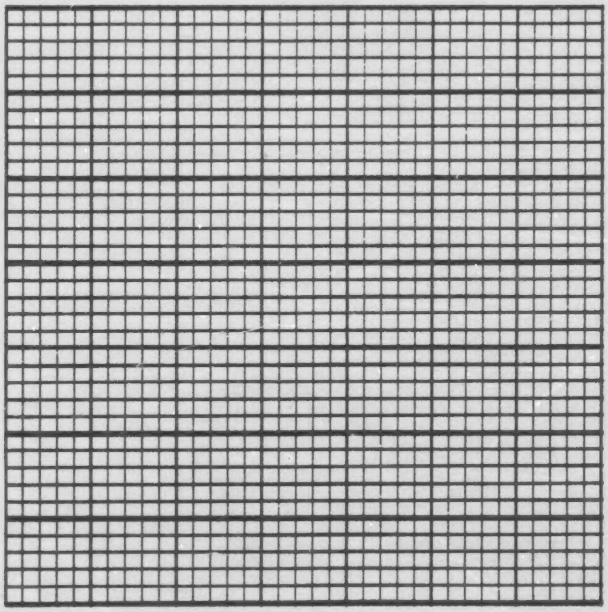
F. Replace or check your components if lamp does not glow or if it does not vary in intensity

G. Connect one channel of oscilloscope to gate of SCR; connect other channel to anode

H. Adjust potentiometer slowly in both directions; observe oscilloscope waveforms

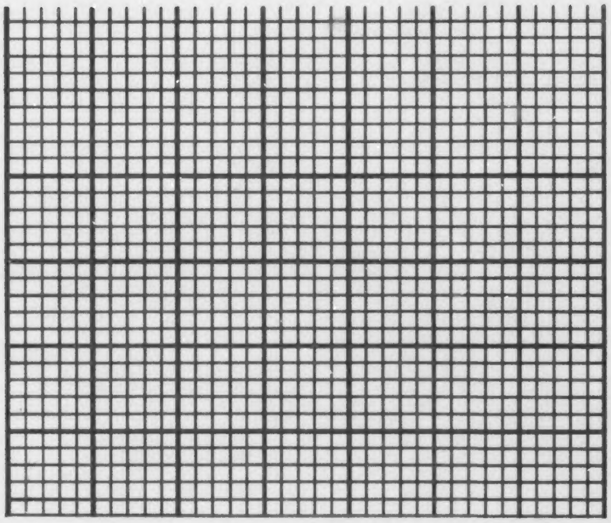
I. Sketch the two waveforms on the following graphs

GATE WAVEFORM



JOB SHEET #4

ANODE WAVEFORM



(NOTE: Discuss your results with the instructor.)

J. Clean work area; put away equipment and materials

GIE - 265-A

SPECIAL SEMICONDUCTOR DEVICES
UNIT IV

TEST

NAME ________________________________ SCORE ____________

1. Match to their correct definitions terms associated with special semiconductor devices. Write the correct numbers in the blanks. Definitions are continued on the next page.

______a. Electrode of a field-effect transistor corresponding to the collector of a bipolar transistor

______b. Measure of the restriction to current at the input of a device

______c. Electrode of various semiconductor devices that provides control for operation

______d. Base material upon or within which semiconductor devices are constructed

______e. Electrode of a field-effect transistor corresponding to the emitter of a bipolar transistor

______f. Electromagnetic force that controls conduction in field-effect transistors

______g. Area within semiconductor material where charge carriers are neutralized and current cannot flow

______h. Narrow path within a field-effect transistor through which conduction of current is controlled

______i. Voltage level at which a diode device will switch on and conduct current

______j. Field-effect transistor operation in which a positive voltage on the gate attracts electrons into the channel and increases conduction

______k. Voltage from the gate to the source of field-effect transistors at which conduction of current ceases

1. Gate
2. Source
3. Field effect
4. Drain
5. Channel
6. Depletion region
7. Pinch-off voltage
8. Substrate
9. Depletion mode
10. Input impedance
11. Breakover voltage
12. Trigger
13. Enhancement mode

TEST

______l. Field-effect transistor operation in which a negative voltage on the gate repels electrons in the channel and reduces conduction

______m. Electrical impulse used to turn devices on and off

2. Match to their correct interpretations abbreviations and acronyms associated with special semiconductor devices. Write the correct numbers in the blanks. Abbreviations and interpretations are continued on the next page.

______a. Field-effect transistor

______b. Junction field-effect transistor

______c. Silicon unilateral switch

______d. Cathode lead; multiplier of 1,000

______e. Emitter lead

______f. Silicon-controlled switch

______g. Unijunction transistor

______h. Silicon-controlled rectifier

______i. Drain source voltage

______j. Capacitor

______k. Load resistor in drain circuit of field-effect transistor circuit

______l. Gate source voltage

______m. Metal-oxide semiconductor field-effect transistor

______n. Insulated-gate field-effect transistor

______o. p-material

______p. Anode lead

______q. Substrate lead

______r. Light-activated silicon-controlled rectifier

1. MOSFET
2. UJT
3. FET
4. SCS
5. LASCR
6. JFET
7. P
8. R_D
9. SUS
10. IGFET
11. SCR
12. V_{GS}
13. V_{DS}
14. C
15. K
16. A
17. U
18. E

TEST

______s. Bias resistor connected to gate in field-effect transistor circuit

______t. Source lead

______u. Dual-gate field-effect transistor

______v. Gate source voltage at pinch-off

______w. Drain lead

______x. Source resistor in field-effect transistor circuit

______y. Gate lead

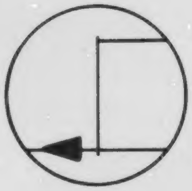
______z. n-material

______aa. Drain supply voltage

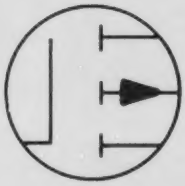
______bb. Base lead

19. V_{DD}
20. V_{GSP}
21. S
22. D
23. G
24. B
25. DGFET
26. R_S
27. R_G
28. N

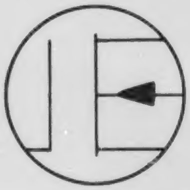
3. Label special semiconductor device schematic symbols. Write the correct names in the blanks. Some answers may be used more than once.



a. ______________________________



b. ______________________________



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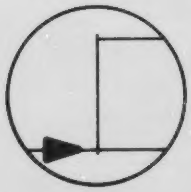
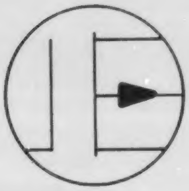
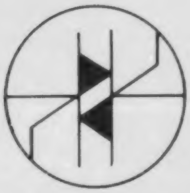


d. ______________________________

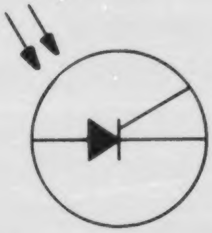
TEST



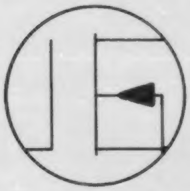
e. ______________________________



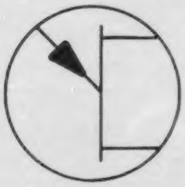
f. ______________________________



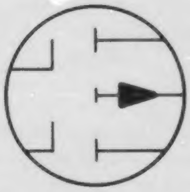
g. ______________________________



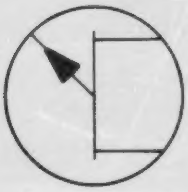
h. ______________________________



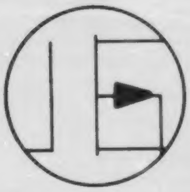
i. ______________________________



j. ______________________________

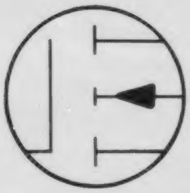


k. ______________________________

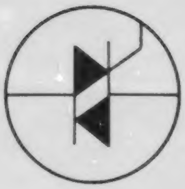


l. ______________________________

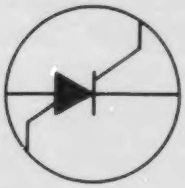
TEST



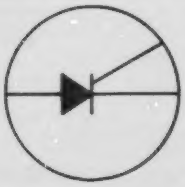
m. ______________________________



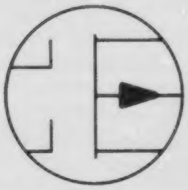
n. ______________________________



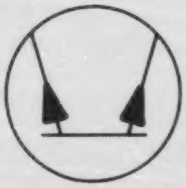
o. ______________________________



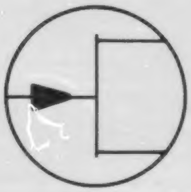
p. ______________________________



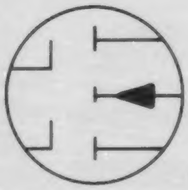
q. ______________________________



r. ______________________________



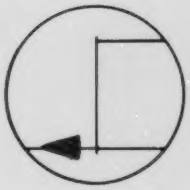
s. ______________________________

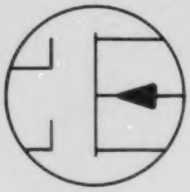


t. ______________________________

240 239

TEST





u. ______________________________ v. ______________________________

4. Distinguish among field-effect transistor bias conditions and their effects. In the blank before each effect, write an *"N"* for no bias; a *"VL"* for V_{DS} equals positive and V_{GS} equals negative but less than V_{GSP}; and a *"V"* for V_{DS} equals positive and V_{GS} equals negative at V_{GSP}.

______a. Depletion region is wide enough to close the channel

______b. Channel is wide

______c. Channel width varies according to V_{GS}

______d. No conduction takes place

______e. Depletion region is narrow

______f. Depletion region is controlled by V_{GS}

______g. Conduction varies according to V_{GS}

5. Distinguish between characteristics of bipolar and field-effect transistors. Write a "B" before bipolar characteristics, and an "FET" before field-effect characteristics.

______a. Are voltage-controlled devices

______b. Are current-controlled devices

______c. Are less sensitive to radiation

______d. Are less sensitive to heat

______e. Have higher power ratings

______f. Have higher input impedance

______g. Have higher frequency response

______h. Are able to operate at higher voltage

______i. Produce less noise

______j. Are more sensitive to static

TEST

6. Match special semiconductor devices to their correct applications. Write the correct numbers in the blanks.

_____a. Switches on or off in either direction as controlled by two gates; used as AC power controller or AC electronic switch

_____b. Serves as high-input impedance device for amplifying input voltage variations applied to gate; used as amplifier

_____c. Switches on and off according to voltages and bias applied; used as oscillator or pulse generator

_____d. Rectifies AC to DC according to timing of electrical impulse to gate lead; used as controllable rectifier and frequently as a switch

_____e. Switches on in either direction when voltage levels reach breakover voltage; used to provide triggering to AC control circuits

_____f. Switches on according to gate potential and intensity of light; used to control outdoor lighting circuits and other light-affected processes

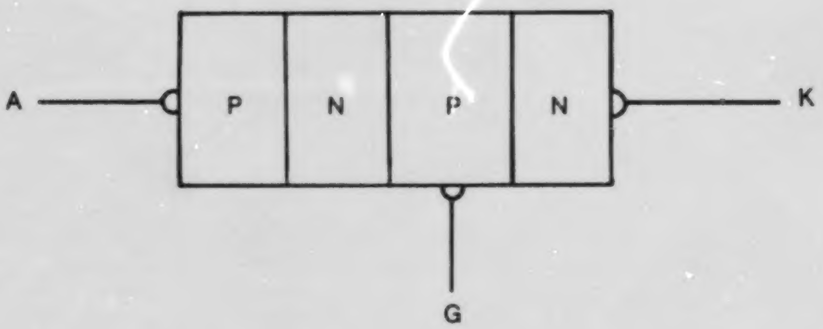
_____g. Switches on in either direction when gate is triggered; used to vary AC power

_____h. Switches on or off by triggering either of two gates, but conducts current in only one direction; used as variable output rectifier or as DC electronic switch

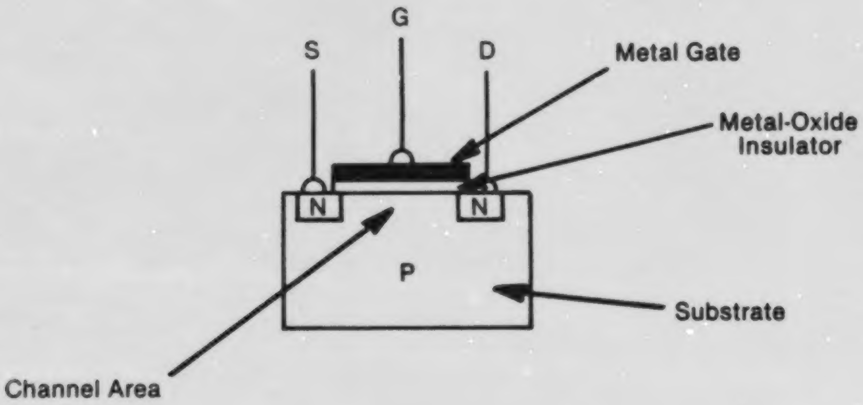
1. SCR
2. LASCR
3. SUS
4. FET
5. Triac
6. Diac
7. SCS
8. UJT

TEST

7. Label structures of common special semiconductor devices.

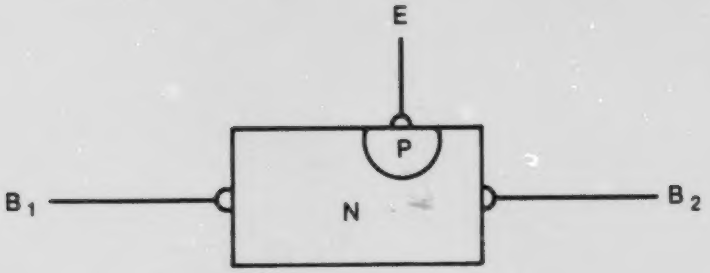


a. ______________________________

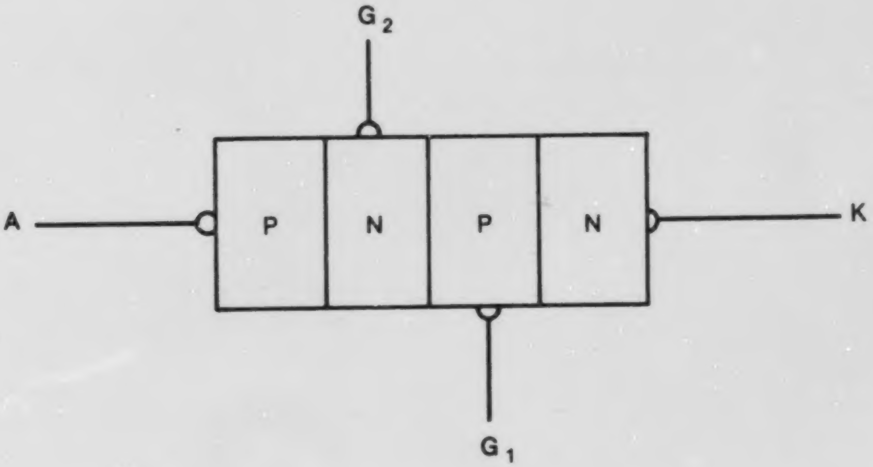

G
S
D
Metal Gate
Metal-Oxide Insulator
N
N
P
Substrate
Channel Area

b. ______________________________

TEST



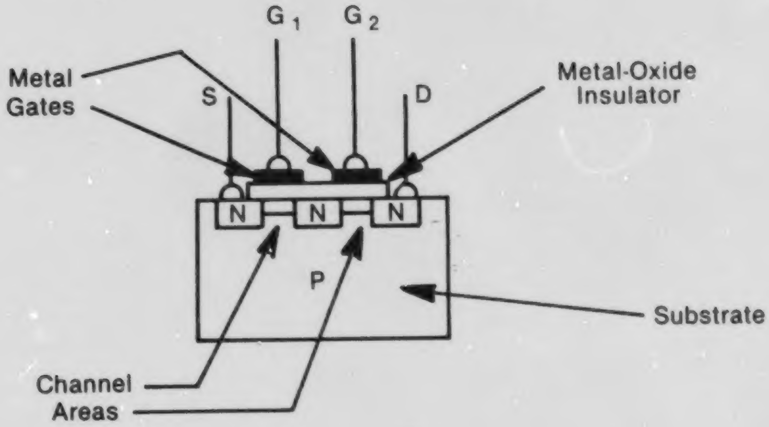
c. ______________________________


G2
A
P
N
P
N
K
G1

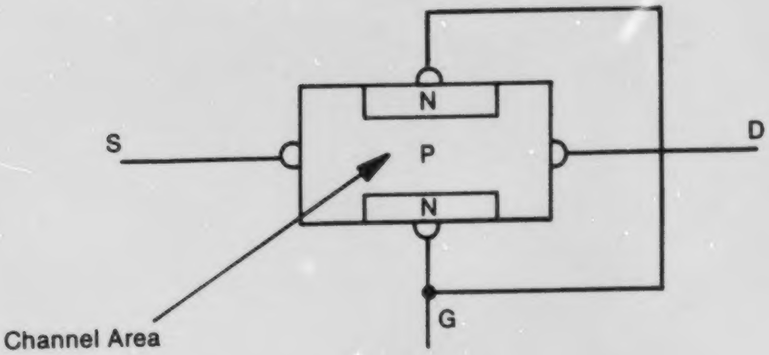
d. ______________________________

274-A

TEST


G1
G2
Metal Gates
S
D
Metal-Oxide Insulator
N
N
N
P
Substrate
Channel Areas

e. ____

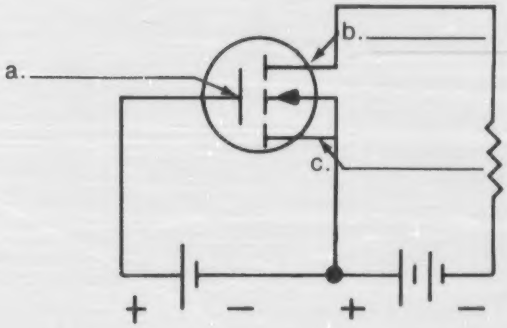

N
S
P
D
N
G
Channel Area

f. ____

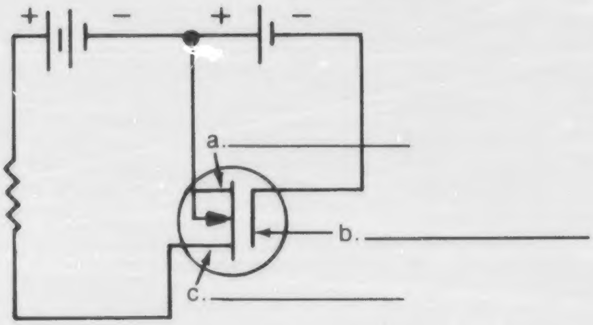
TEST

8. Label schematics to show bias in common applications of field-effect transistors.

MOSFET, enhancement mode

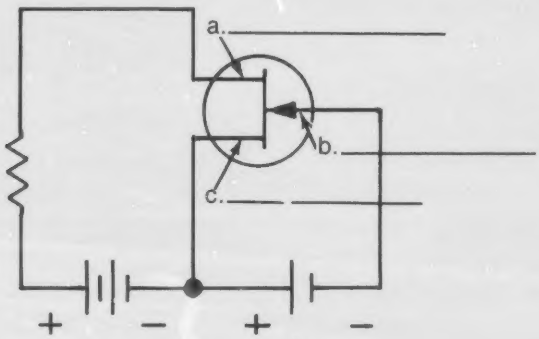


MOSFET, depletion mode



TEST

Junction device, n-channel FET



(NOTE: Test question 9 lists the job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

9. Demonstrate the ability to

   a. Use a transistor tester to test various special semiconductor devices.

   b. Analyze a silicon-controlled rectifier circuit.

   c. Construct and analyze a unijunction transistor oscillator circuit.

   d. Observe waveforms of a silicon-controlled rectifier circuit.

SPECIAL SEMICONDUCTOR DEVICES
UNIT IV

ANSWERS TO TEST

1.	a.	4	e.	2	h.	5	k.	7
	b.	10	f.	3	i.	11	l.	9
	c.	1	g.	6	j.	13	m.	12
	d.	8						

2.	a.	3	h.	11	o.	7	v.	20
	b.	6	i.	13	p.	16	w.	22
	c.	9	j.	14	q.	17	x.	26
	d.	15	k.	8	r.	5	y.	23
	e.	18	l.	12	s.	27	z.	28
	f.	4	m.	1	t.	21	aa.	19
	g.	2	n.	10	u.	25	bb.	24

3. a. p-channel FET
   b. p-channel MOSFET, enhancement mode
   c. n-channel MOSFET, depletion mode
   d. n-channel FET
   e. p-channel MOSFET, depletion mode
   f. Silicon unilateral switch (SUS)
   g. Light-activated silicon-controlled rectifier (LASCR)
   h. n-channel MOSFET, depletion mode
   i. Unijunction transistor (UJT), n-type base
   j. p-channel dual-gate MOSFET, enhancement mode

ANSWERS TO TEST

k. Unijunction transistor (UJT), p-type base

l. p-channel MOSFET, depletion mode

m. n-channel MOSFET, enhancement mode

n. Triac

o. Silicon-controlled switch (SCS)

p. Silicon-controlled rectifier (SCR)

q. p-channel dual-gate MOSFET, depletion mode

r. Diac

s. n-channel FET

t. n-channel dual-gate MOSFET, enhancement mode

u. p-channel FET

v. n-channel dual-gate MOSFET, depletion mode

4.	a.	V	e.	N
	b.	N	f.	VL
	c.	VL	g.	VL
	d.	V		

5.	a.	FET	f.	FET
	b.	B	g.	B
	c.	FET	h.	FET
	d.	FET	i.	FET
	e.	B	j.	FET

6.	a.	3	e.	6
	b.	4	f.	2
	c.	8	g.	5
	d.	1	h.	7

ANSWERS TO TEST

7. a. SCR
   b. p-channel MOSFET
   c. UJT
   d. SCS
   e. p-channel DGFET
   f. p-channel FET

8. MOSFET, enhancement mode
   a. G
   b. D
   c. S

   MOSFET, depletion mode
   a. S
   b. G
   c. D

   Junction device, n-channel FET
   a. S
   b. G
   c. D

9. Performance skills evaluated to the satisfaction of the instructor

AMPLIFIER CIRCUITS
UNIT I

SUGGESTED ACTIVITIES

I. Suggested activities

  A. Make transparencies.

  B. Provide students with objective sheet.

  C. Discuss unit and specific objectives.

  D. Provide students with information, assignment, and job sheets.

  E. Discuss information and assignment sheets.

  F. Demonstrate and discuss procedures outlined in job sheets.

  G. Explain that amplifiers are the basic building blocks of all electronic equipment. Use an industrial schematic diagram to point out types of amplifiers built into the circuitry.

  H. While demonstrating Job Sheet #2, show the effects of overdriving an amplifier to produce distortion and classes of amplification on the oscilloscope. Show frequency response as the amplitude varies over a range of frequencies.

  I. Provide students with faulty components so that they may troubleshoot the common-emitter amplifier in Job Sheet #3.

  J. Give test.

  K. Reteach if necessary.

II. Instructional materials

  A. Objective sheet

  B. Suggested activities

  C. Information sheet

  D. Transparency masters

    1. TM #1 — Power Dissipation Curve

    2. TM #2 — Transistor Load Line

    3. TM #3 — Quiescent Point

SUGGESTED ACTIVITIES

E. Assignment sheets

   1. Assignment Sheet #1 — Plot a Power Dissipation Curve, Draw a Load Line, and Locate the Quiescent Point

   2. Assignment Sheet #2 — State Whether Power Should Be On or Off During Various Troubleshooting Steps

F. Answers to assignment sheets

G. Job sheets

   1. Job Sheet #1 — Construct and Analyze a Common-Emitter Amplifier

   2. Job Sheet #2 — Analyze the Complementary-Symmetry Amplifier

   3. Job Sheet #3 — Troubleshoot a Common-Emitter Amplifier

H. Test

I. Answers to test

III. Unit references

A. Alley, Charles L., and Kenneth W. Atwood. *Electronics Engineering,* 3rd ed. New York: John Wiley and Sons, 1973.

B. Chirlian, Paul M. *Electronics Circuits: Physical Principles, Analysis, and Design.* New York: McGraw-Hill Book Company, 1971.

C. *Graphic Symbols for Electrical and Electronics Diagrams.* New York: Institute of Electrical and Electronics Engineers, 1981.

D. Grob, Bernard. *Basic Electronics,* 4th ed. New York: McGraw-Hill Book Company, 1977.

AMPLIFIER CIRCUITS
UNIT I

INFORMATION SHEET

I. Terms and definitions

A. Amplifier — Circuit containing one or more active devices controlled by a voltage or current input that alters the power or waveform of the output

B. Active device — Electron tube or solid-state component capable of controlling relatively large values of output power with a small power input

C. Gain — Ratio of output to input

D. Half-power point — Power output 0.707 of peak power

E. Bandwidth — Range of frequencies between half-power points

F. Distortion — Undesirable changes in output signal

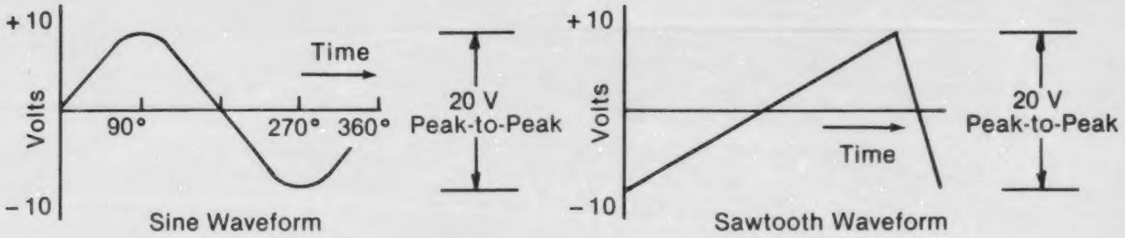
G. Feedback — Process of routing a portion of a circuit's output power back to its input in order to provide control

(NOTE: Feedback can be positive, tending to increase output, or negative, tending to reduce output and increase stability.)

H. Analog signal — Continuous signal varying in amplitude as contrasted to digital signals, which vary in frequency and position of pulses (Figures 1 and 2)

EXAMPLES:

FIGURE 1

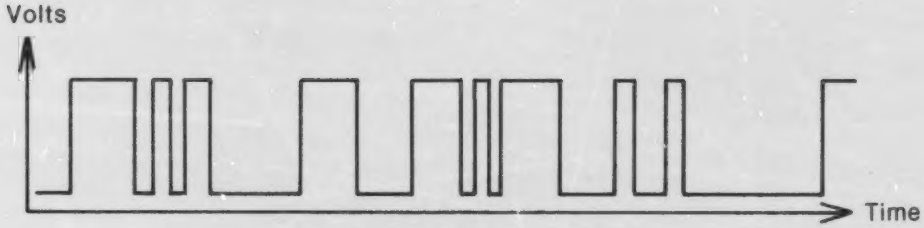


Analog Signal As It May Appear on an Oscilloscope

Source: McGraw-Hill Book Company.

INFORMATION SHEET

FIGURE 2



Digital Signal as it May Appear on an Oscilloscope

I. Modulation — Conversion of information into electronic signals

J. Stage — Section of circuitry

(NOTE: A stage may contain an amplifier or be an "amplifier stage.")

K. Coupling — Method of connecting signals between stages or circuits

L. Saturation — State when all normal charge carriers are flowing in a device

M. Cutoff — State when all normal charge carriers stop flowing in a device

N. Quiescent point — Point on the characteristic curves graph of an amplifier; represents the conditions that exist when the input signal is not applied

II. Symbols and abbreviations

A. IC — Integrated circuit

B. A, amp — Amperes

C. AMP — Amplifier

D. Q — Schematic designator for a transistor

E. XSTR — Transistor

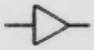
F. XFMR — Transformer

G. I_C — Collector current

H. Bw — Bandwidth

I. R_t — Total resistance

INFORMATION SHEET

J.  — Amplifier symbol

(NOTE: This symbol and variations of it are used in analog control diagrams, logic circuit diagrams, and as an integrated circuit amplifier in schematic diagrams. The symbol arrow points toward the output.)

K. V_{CC} — Collector supply voltage

L. R_L — Load resistor

M. B — Greek letter beta; designates current gain

N. LC — Inductive/capacitive circuit

O. RC — Resistive/capacitive circuit

P. OSHA — Occupational Safety and Health Administration

Q. dBA — A-scale decibels

R. MOS — Metal-oxide semiconductor

S. SPST — Single-pole, single-throw switch

T. Ω — Ohm

U. IGFET — Insulated gate, field-effect transistor

V. I_B — Base current

III. Types of amplifiers and their uses

A. Preamplifier (pre-amp) — Used to boost input power sufficiently so that following circuitry can operate effectively

B. Buffer amplifier (buffer amp) — Used to isolate one circuit from another to reduce interference or loading of previous circuit

C. Operational amplifier (op-amp) — Used for a variety of circuit applications including use as multiplier, divider, summer, integrator, differentiator, amplifier, and comparator

D. Linear amplifier — Used in circuits where low distortion is required

E. Power amplifier — Used to produce large amounts of power in order to drive an output device such as a servomotor or speaker

(NOTE: A power amplifier may also be called a *driver amp* or *final driver*.)

INFORMATION SHEET

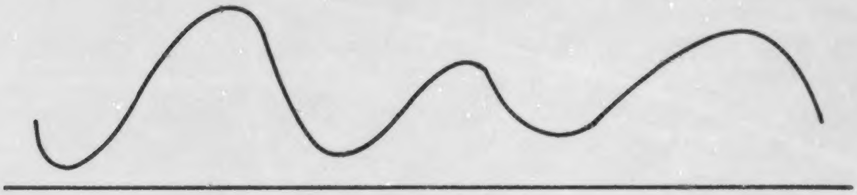
F. Mixer amplifier — Used to combine two frequencies

G. Chopper amplifier — Used to convert an analog signal into a pulse-frequency modulated signal by switching on and off at a frequency higher than the input frequency (Figures 3 and 4)

(NOTE: Chopping should not be confused with another conversion process known as *analog-to-digital conversion*.)

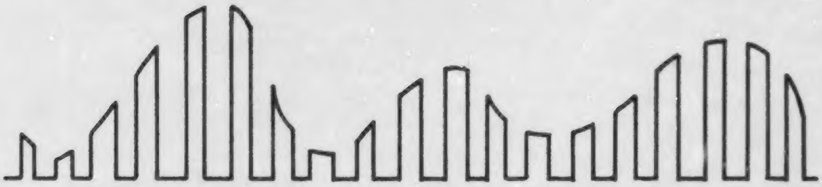
EXAMPLES:

FIGURE 3



Input to a Chopper Amplifier

FIGURE 4



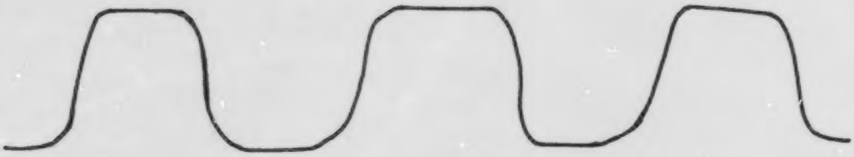
Output from a Chopper Amplifier

INFORMATION SHEET

H. Squaring amplifier — Used to produce square waveforms for digital circuits from waveforms that may be rounded due to previous distortion (Figures 5 and 6)

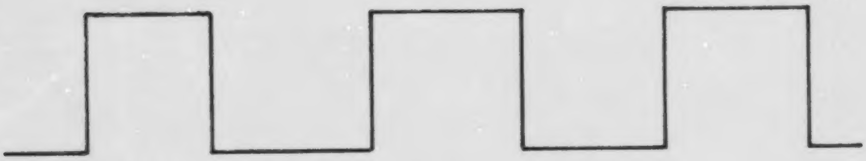
EXAMPLES:

FIGURE 5



Input to a Squaring Amplifier

FIGURE 6



Squaring Amplifier Output

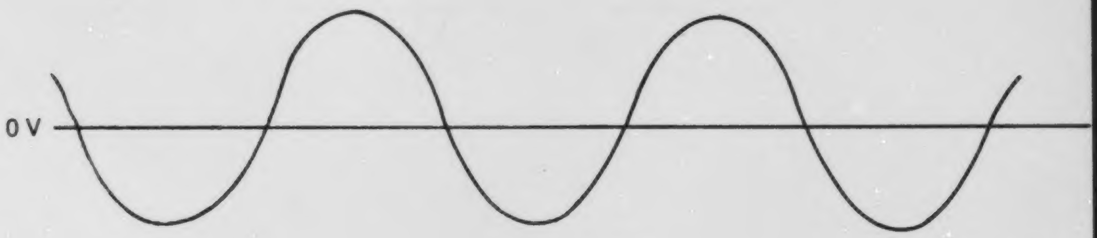
INFORMATION SHEET

IV. Classes of amplification (Figures 7-11)

(NOTE: The input signal for the following classifications of amplifiers is shown in Figure 7.)

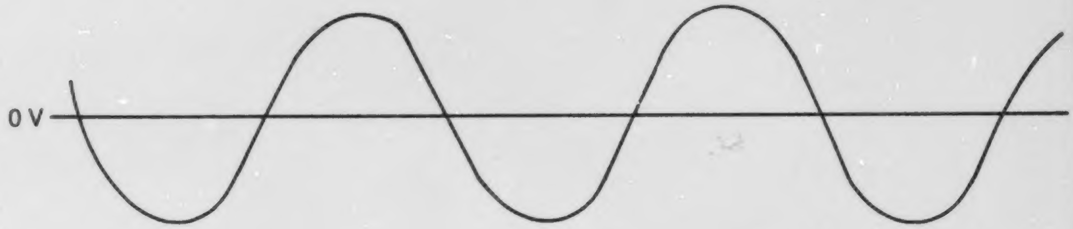
EXAMPLE:

FIGURE 7



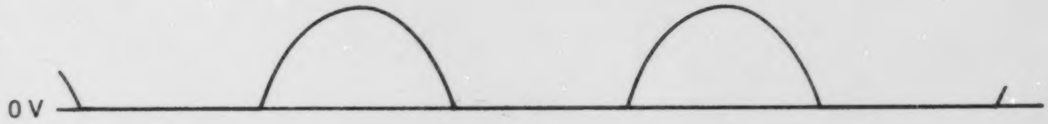
A. Class A

FIGURE 8



B. Class B

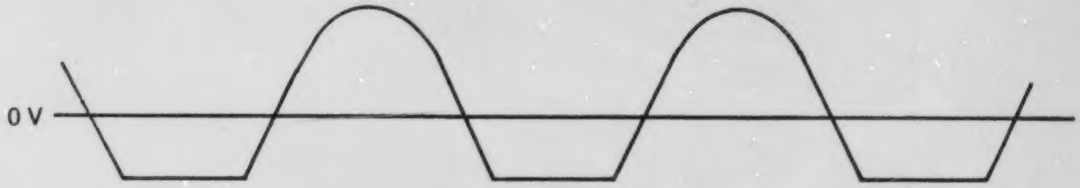
FIGURE 9



INFORMATION SHEET

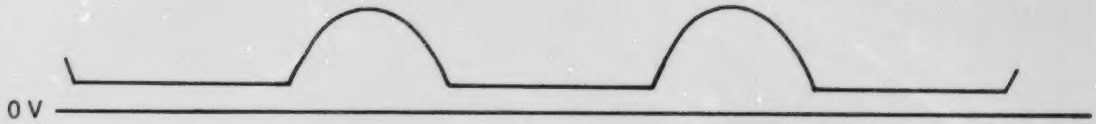
C. Class AB

FIGURE 10



D. Class C

FIGURE 11



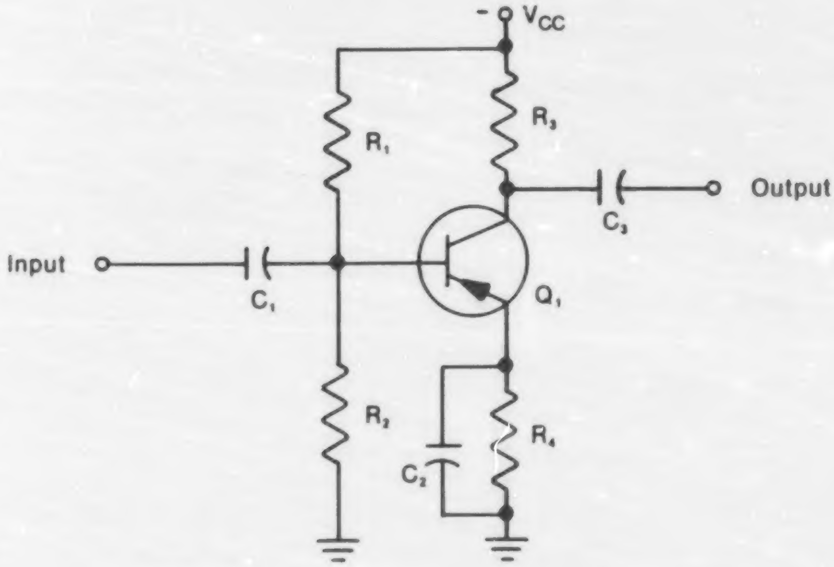
INFORMATION SHEET

V. Amplifier circuits

A. Common-emitter (Figure 12)

(NOTE: The input is to the base, and the output is from the collector. The emitter is said to be *in common* to input and output; thus the circuit is referred to as a *common-emitter amplifier*.)

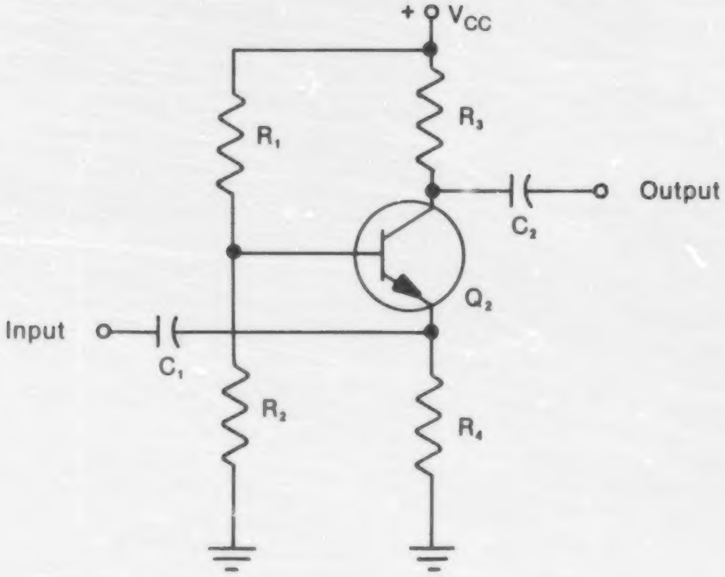
FIGURE 12


- Vcc
R₁
R₃
Output
C₃
Input
C₁
Q₁
R₂
C₂
R₄

INFORMATION SHEET

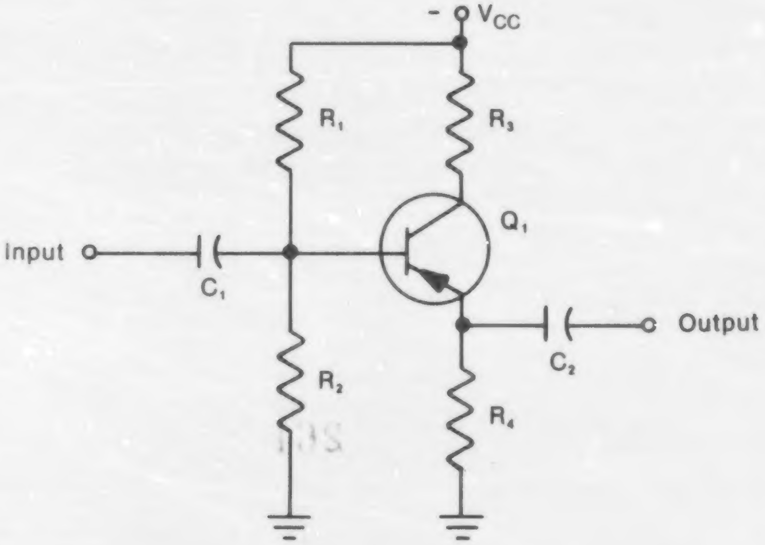
B. Common-base (Figure 13)

FIGURE 13


+ Vcc
R1
R3
Output
C2
Q2
Input
C1
R2
R4

C. Common-collector (Figure 14)

FIGURE 14

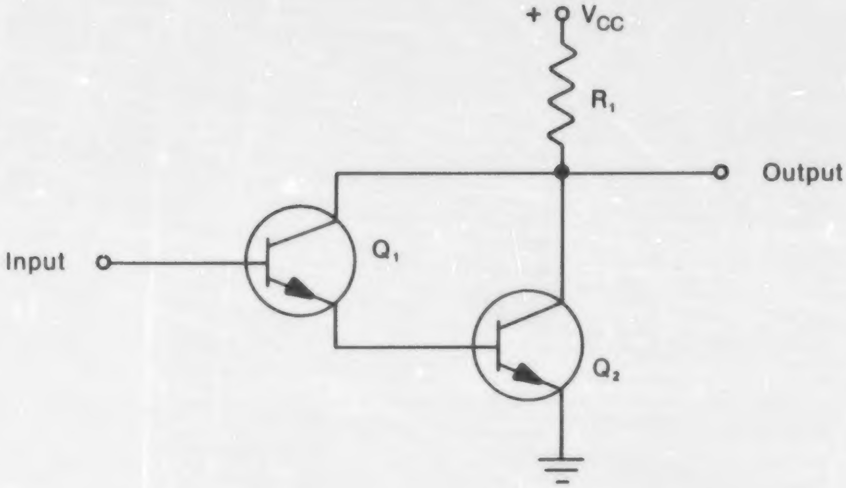

- Vcc
R1
R3
Q1
Input
C1
Output
C2
R2
R4

INFORMATION SHEET

D. Darlington (Figure 15)

(NOTE: The Darlington amplifier is recognized by the emitter current of one transistor's output directly supplying the base current of the second transistor. Sometimes the first transistor is smaller than the second because a small transistor's emitter current can easily supply a large transistor's base current.)

FIGURE 15

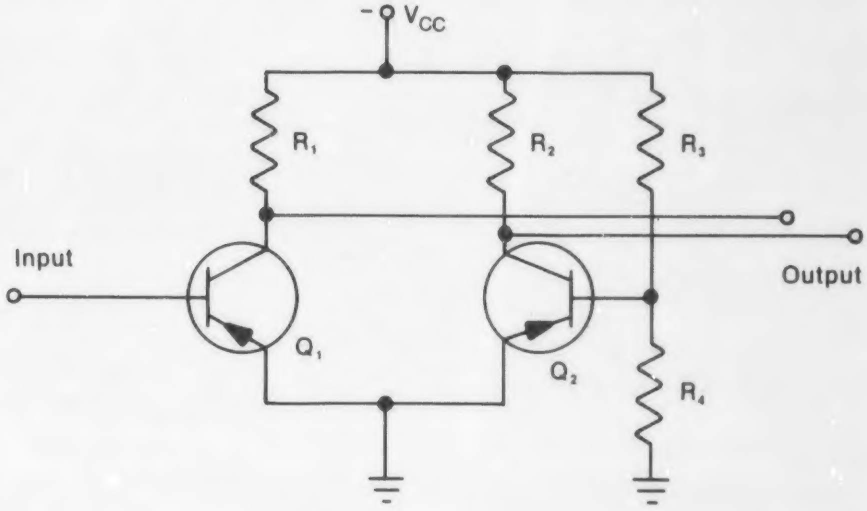


INFORMATION SHEET

E. Differential (Figure 16)

(NOTE: The differential amplifier may have one or two inputs and either one or two outputs. It amplifies the difference between the two transistors' base voltages. Often one base voltage is fixed at a reference level.)

FIGURE 16

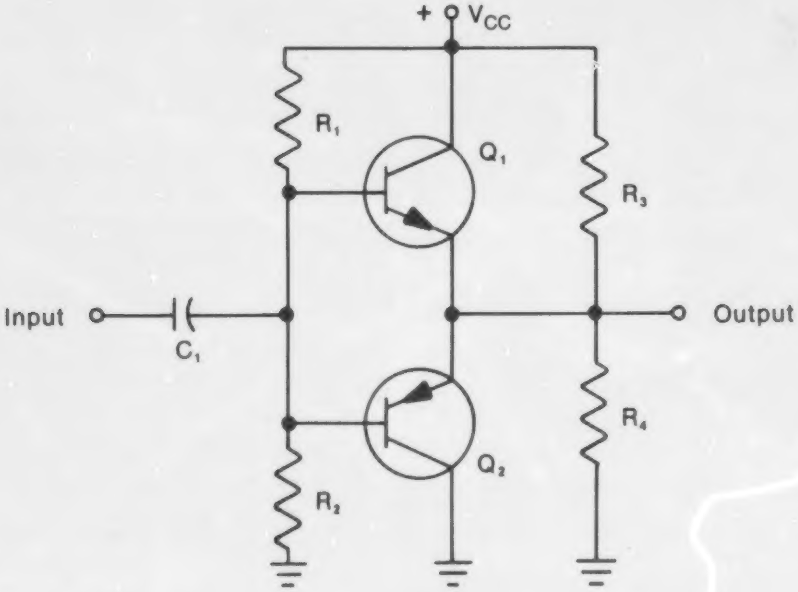

- V_{CC}
R_1
R_2
R_3
Input
Output
Q_1
Q_2
R_4

INFORMATION SHEET

F. Complementary-symmetry (Figure 17)

(NOTE: One transistor is a pnp and one is an npn. The circuit relies on matched transistors to reduce distortion because one amplifies the negative portion of signals and the other amplifies the positive.)

FIGURE 17

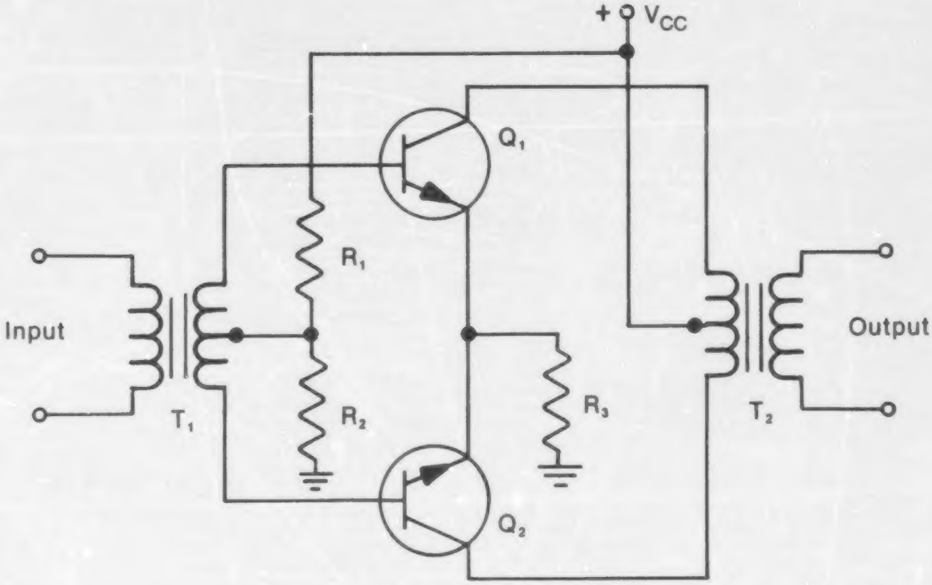

+ Vcc
R1
Q1
R3
Input
C1
Output
R4
Q2
R2

INFORMATION SHEET

G. Push-pull (Figure 18)

(NOTE: The push-pull amplifier uses two identical transistors. This sets it apart from the complementary-symmetry amplifier. Transformers are used to divide the signal so that one transistor amplifies the negative and the other amplifies the positive.)

FIGURE 18

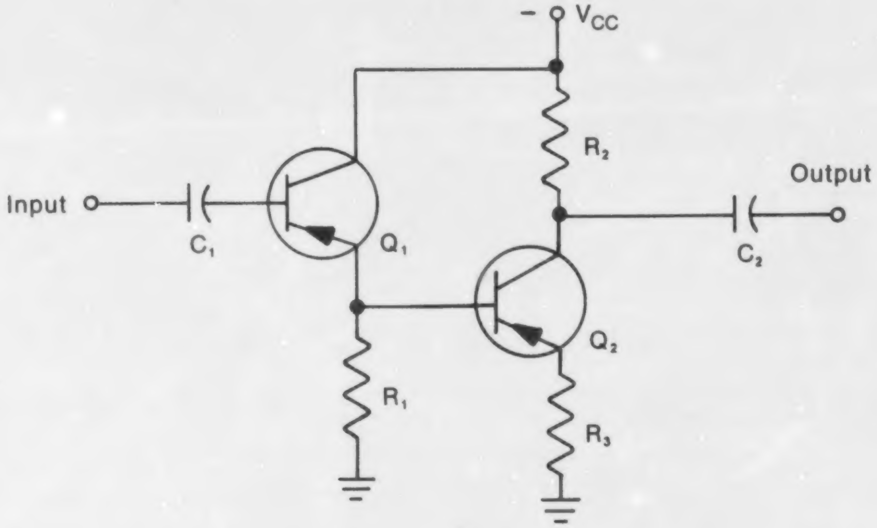


INFORMATION SHEET

H. Cascade (direct-coupled) (Figure 19)

(NOTE: The cascade amplifier is simply a multiple-stage amplifier with one stage connected directly to the next.)

FIGURE 19

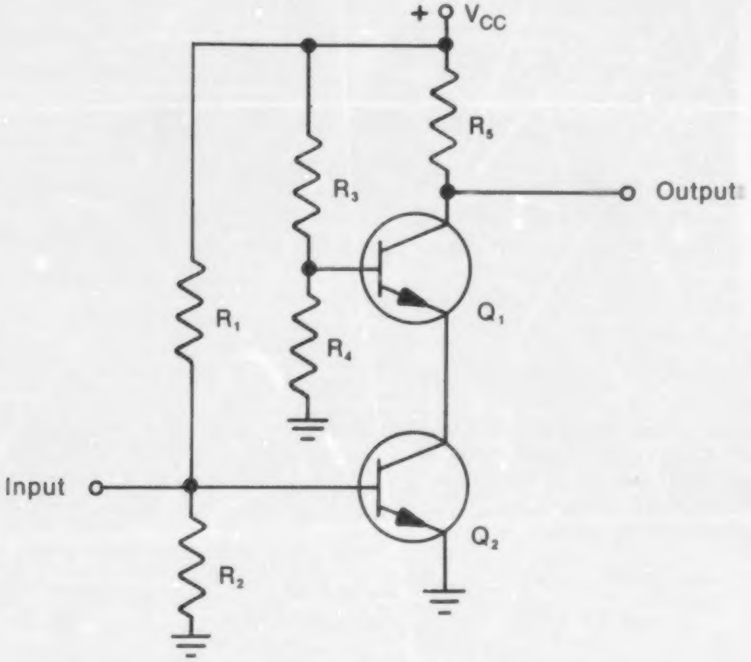

– Vcc
R₂
Output
Input
C₁
Q₁
C₂
Q₂
R₁
R₃

INFORMATION SHEET

I. Cascode amplifier (Figure 20)

(NOTE: The cascode amplifier is characterized by both transistors passing the same current in series. Virtually any amplifier circuit can be constructed of vacuum tubes, bipolar transistors, or FETs, with the exception of the Darlington amplifier, which cannot work with IGFETs.)

FIGURE 20



VI. Characteristics of amplifier coupling techniques

A. Direct

1. Allows for DC coupling
2. Reduces cost by eliminating components
3. Allows bias interference between stages

EXAMPLES: The Darlington and cascode amplifiers discussed in Section V are directly coupled.

B. Capacitor

1. Blocks DC

INFORMATION SHEET

2. Allows instant coupling of sharp-rise time pulses

EXAMPLES: The common-emitter, common-collector, and common-base amplifiers shown in Section V have capacitors to couple with the previous stage as well as the following stage.

C. Resistor

1. Couples AC and DC, but provides some isolation between stages

2. Provides for base biasing by DC from the previous stage

EXAMPLE: The squaring amplifier shown in Figure 24 has resistor coupling at its input.

D. Transformer

1. Blocks DC

2. Impedes surges

EXAMPLE: The push-pull amplifier shown in Figure 18 has transformer-coupled input and output.

E. Optical

1. Provides complete isolation between stages

2. Couples very low frequencies

EXAMPLE: In order to isolate extremely high voltages, a coupling using a light-transmitter output of one stage can couple to a photodevice of another stage.

(NOTE: This method is also used in the conversion of fiber optic signals to and from electronic circuits.)

F. Tuned (Figures 21-23)

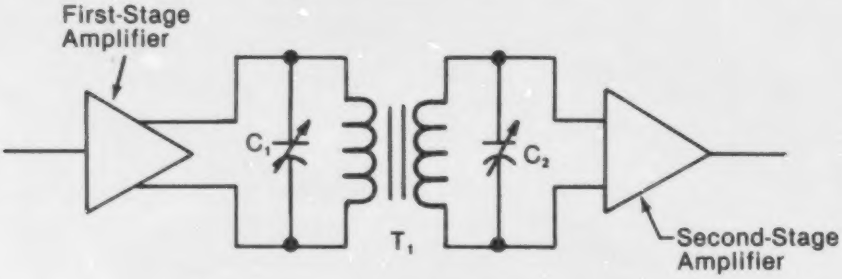
1. Allows for passing or blocking one range of frequencies

INFORMATION SHEET

2. Can be an LC coupling (inductor and capacitor) or a transformer and capacitor coupling

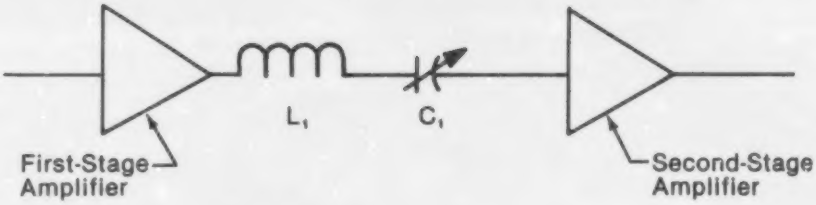
EXAMPLES:

FIGURE 21


First-Stage Amplifier
C_1
T_1
C_2
Second-Stage Amplifier

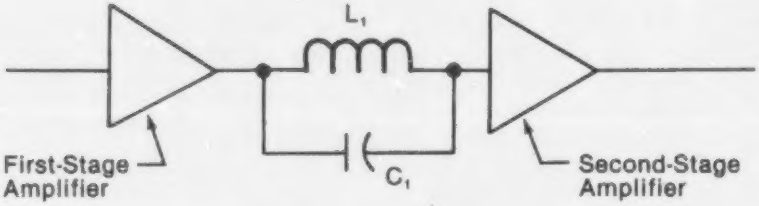
Double-Tuned Transformer: Passes a Given Range of Frequencies

FIGURE 22


L_1
C_1
First-Stage Amplifier
Second-Stage Amplifier

LC Coupling: Passes Within a Given Range of Frequencies

FIGURE 23


L_1
C_1
First-Stage Amplifier
Second-Stage Amplifier

LC Coupling: Blocks a Given Range of Frequencies

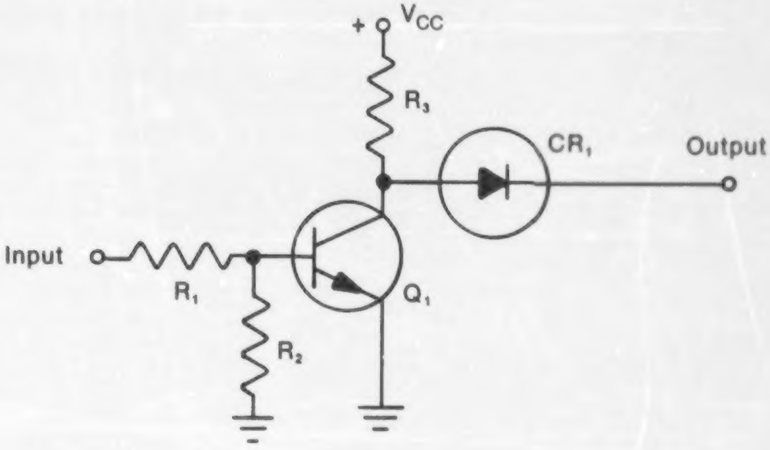
INFORMATION SHEET

G. Diode (Figures 24 and 25)

1. Blocks DC in one direction and rectifies AC in one direction
2. Can be used to direct positives or negatives to particular circuits

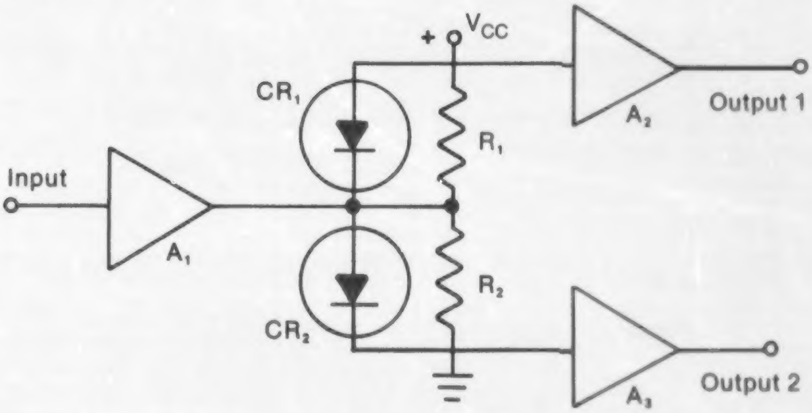
EXAMPLES: The squaring amplifier illustrated in Figure 24 has a diode-coupled output to prevent the DC bias of the following stage from forcing the transistor too far into saturation, which would increase its response time.

FIGURE 24 Squaring Amplifier



+
V_{CC}
R_3
CR_1
Output
Input
R_1
Q_1
R_2

FIGURE 25



+
V_{CC}
CR_1
R_1
A_2
Output 1
Input
A_1
R_2
CR_2
A_3
Output 2

(NOTE: When the diodes are connected between stages as in Figure 25, they are called *steering diodes* because they steer positives in one direction and negatives in the other.)

INFORMATION SHEET

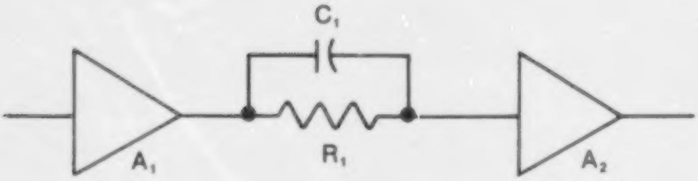
H. RC (resistor and capacitor)

1. Provides for DC coupling

2. Provides for coupling fast-changing signals

EXAMPLE: The capacitor in the coupling in Figure 26 passes rapid changes while the resistor allows slow changes (low frequency and DC) to be coupled. The capacitor is called a *speed-up cap*.

FIGURE 26



I. Inductive

1. Seldom used as a single component

2. Allows DC but impedes high frequency or rapid changes

VII. Calculating current gain of a Darlington amplifier

A. Determine from manufacturer's specification reference manual the beta of each transistor

EXAMPLE: $Q_1\ B = 50$

$Q_2\ B = 20$

B. Multiply the betas of the two transistors to find current gain

EXAMPLE: $B_t = B_{Q_1} \times B_{Q_2}$

$= 50 \times 20$

$= 1{,}000$

INFORMATION SHEET

VIII. Steps for troubleshooting amplifier circuits (Assignment Sheet #1)

(CAUTION: Damage may result to circuitry or test equipment, or personal injury may result if certain checks are made with the power on. Only signal tracing, voltage measurement, and control-panel monitoring should be done with the power on.)

(NOTE: The steps required will vary with working conditions. For example, work on a circuit board in a shop will probably be different than troubleshooting an amplifier circuit in a factory machine.)

A. Make visual circuit inspection

1. Look for burned components — Power off
2. Look for broken components — Power off
3. Look for loose or disconnected components — Power off
4. Look for cracked or discolored printed circuit boards — Power off

B. Make voltage checks

1. Check power supply voltage levels — Power on
2. Check calibration voltages at special test points marked on schematic or listed in equipment manual — Power on

C. Trace signals

1. Check first at center stage (of multiple-stage amplifiers) for an input signal — Power on

   (NOTE: This check will quickly show whether or not the problem is in the first half of the system or the latter half.)

2. If signal is detected and is acceptable, continue tracing signal through to output — Power on
3. If signal is not detected, begin tracing back through previous stages until point of signal loss is found — Power on
4. If amplifier is removed from a system that supplies a signal, a test frequency or waveform may be injected from a signal generator connected through a capacitor for DC isolation — Power on
5. Use oscilloscope to trace signal, its amplification, calibration, and possible distortion as it travels from one stage to another — Power on

INFORMATION SHEET

D. Make ohmmeter checks

(NOTE: Ohmmeter checks are not usually performed until the problem has been isolated to a small area of the circuitry.)

1. Check for short circuits between power and ground — Power off

2. Check diodes — Power off

3. Check capacitors — Power off

4. Check transformers — Power off

5. Check inductors — Power off

E. Test diodes and transistors

1. Use in-circuit semiconductor tester to test diodes — Power off

2. Use tester to test transistors — Power off

F. Substitute components

1. Use spare PCBs, and replace one at a time — Power off

   (CAUTION: Never replace PCBs or any component with the power on. Components could be damaged.)

2. Check for proper operation after each PCB is installed — Power on

   (NOTE: Any plug-in component may be easily exchanged in this manner. Some circuits have several identical plug-in sections that can be swapped around to see if the problem changes from one section to another. This is the least acceptable but often the fastest troubleshooting technique. However, by swapping components carelessly, the damage can be spread throughout the equipment. Often, an original problem will cause failure in another section. Then, when a component is swapped with a spare or identical system component, it, too, will be damaged by the source of the original problem.)

IX. Plotting a transistor power dissipation curve (Transparency #1)

A. Use manufacturer's reference manual to determine transistor's maximum continuous power dissipation rating

EXAMPLE: A miniature transistor may be listed as having a 200-milliwatt power dissipation rating.

INFORMATION SHEET

B. Use power formula ($P = IE$) to calculate the collector current for each major division of collector voltage

EXAMPLE: For 25 volts, the current required for 200 milliwatts is found as follows

$$P = IE$$

$$I = \frac{P}{E}$$

$$= \frac{200\text{ mW}}{25\text{ V}}$$

$$= 8\text{ mA}$$

C. Locate point on graph that corresponds to 8 milliamperes of collector current and 25 volts (Transparency #1, Point A)

D. Calculate and mark each point on characteristic curves graph that corresponds to 200 milliwatts for each major voltage division (Transparency #1, Points B through F)

EXAMPLE: $I = \frac{200}{V}$ where $V = 20, 15, 10, 7.5, 5$

Points	Voltage	Current
A	25 V	8 mA
B	20 V	10 mA
C	15 V	13.3 mA
D	10 V	20 mA
E	7.5 V	26.7 mA
F	5 V	40 mA

E. Connect the points with a curved line to make power dissipation curve

(NOTE: The transistor must operate below this line or it will overheat and fail; thus, the load line should be below the power-dissipation curve.)

INFORMATION SHEET

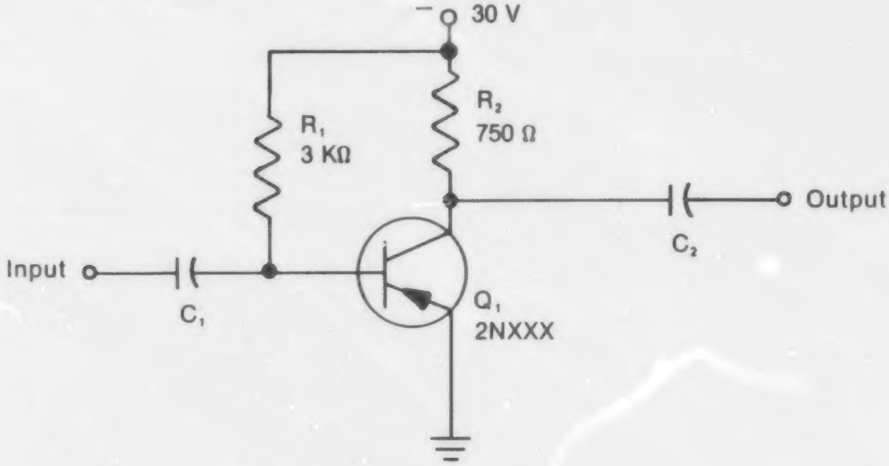
X. Drawing a transistor load line for a single-stage amplifier (Transparency #2)

A. Determine collector voltage when transistor is in cutoff state

(NOTE: The characteristic curves in Transparency #2 are for a fictitious transistor 2NXXX and are for the purpose of illustration only. Each transistor has its own characteristic curves.)

EXAMPLE: The power amplifier shown in Figure 27 has 30 volts potential across the collector-to-emitter of the transistor.

FIGURE 27



Fixed-Bias, Common Emitter, Power Amplifier

B. Mark transistor's collector voltage on "Collector-to-Emitter" axis of graph (Transparency #2, Point A)

(NOTE: Collector voltage is usually marked on the schematic. If not, measure with multimeter.)

INFORMATION SHEET

C. Determine collector current when transistor is in saturation state

(NOTE: The transistor can be assumed to have no resistance in the saturation state.)

EXAMPLE: For the simple circuit shown in Figure 27, the collector current at saturation is the result of 30 volts through R2, and 750 ohms through the transistor to ground. Apply Ohm's law as follows

$$E = IR$$

$$I = \frac{E}{R}$$

$$I_C = \frac{30\ \text{V}}{750\ \Omega}$$

$$= 0.04\ \text{A}$$

$$= 40\ \text{mA}$$

D. Mark collector current on "Collector Current" axis of graph (Transparency #2, Point B)

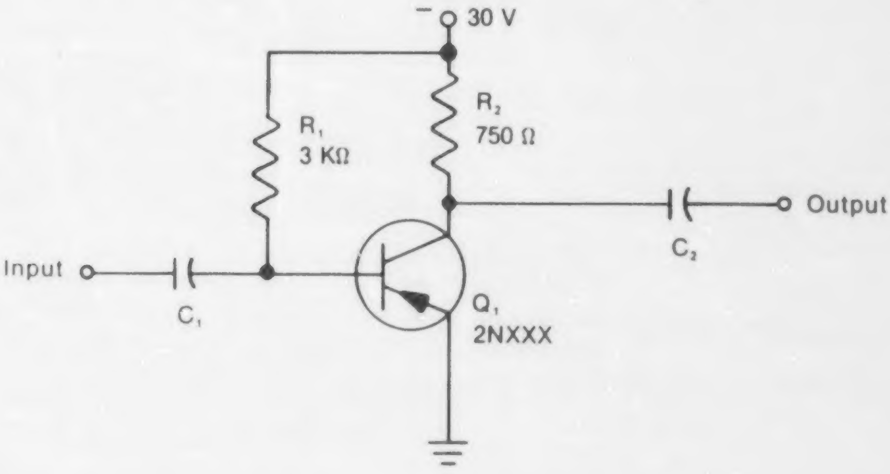
E. Draw a straight line connecting points A and B to indicate transistor load line

(NOTE: Because the transistor will operate between saturation and cutoff, operation will be somewhere along this line if operating in the linear region.)

INFORMATION SHEET

XI. Locating the quiescent point on a transistor load line (Figure 28; Transparency #3)

FIGURE 28 Fixed-Bias, Common Emitter, Power Amplifier



A. Determine base current when no input signal is applied to transistor circuit

EXAMPLE: For the power amplifier illustrated in Figure 28, the base current can be found using Ohm's law.

$$E = IR$$

$$I = \frac{E}{R}$$

$$I_B = \frac{30\text{ V}}{3\text{ K}\Omega}$$

$$= 10\text{ mA}$$

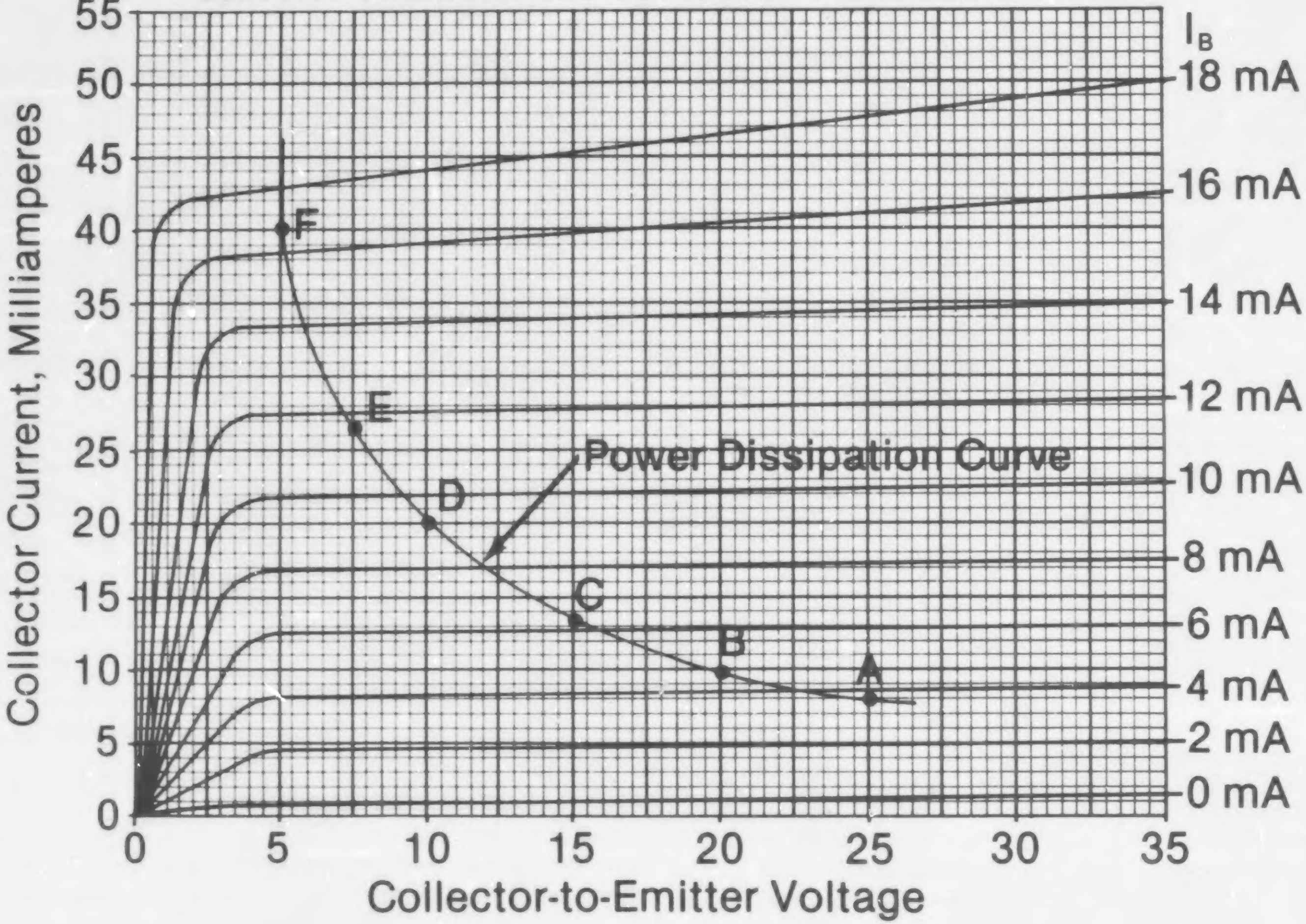
(NOTE: The base-to-emitter voltage is approximately 0.3 volts for a germanium transistor, and approximately 0.6 volts for a silicon transistor. It can be assumed that this effect on calculating the base current is negligible.)

B. Mark quiescent point at intersection of base current and previously drawn load line (Transparency #3, Point Q)

(NOTE: This is the point at which the transistor operates with no input signal. The input signal will vary the base current from this point.)

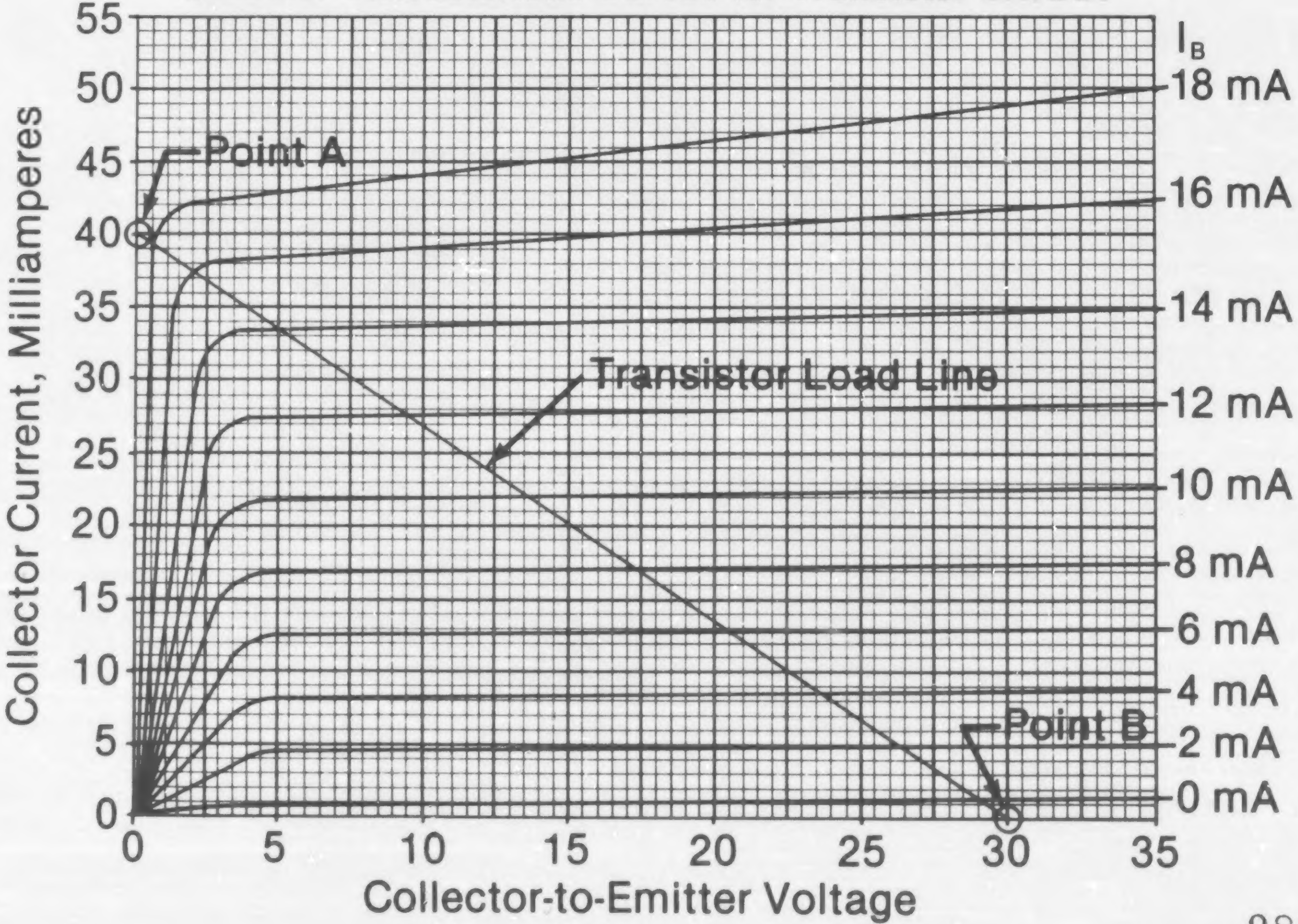
Power Dissipation Curve

Collector Characteristic Curves for Transistor 2NXXX



Transistor Load Line

Collector Characteristic Curves for Transistor 2NXXX

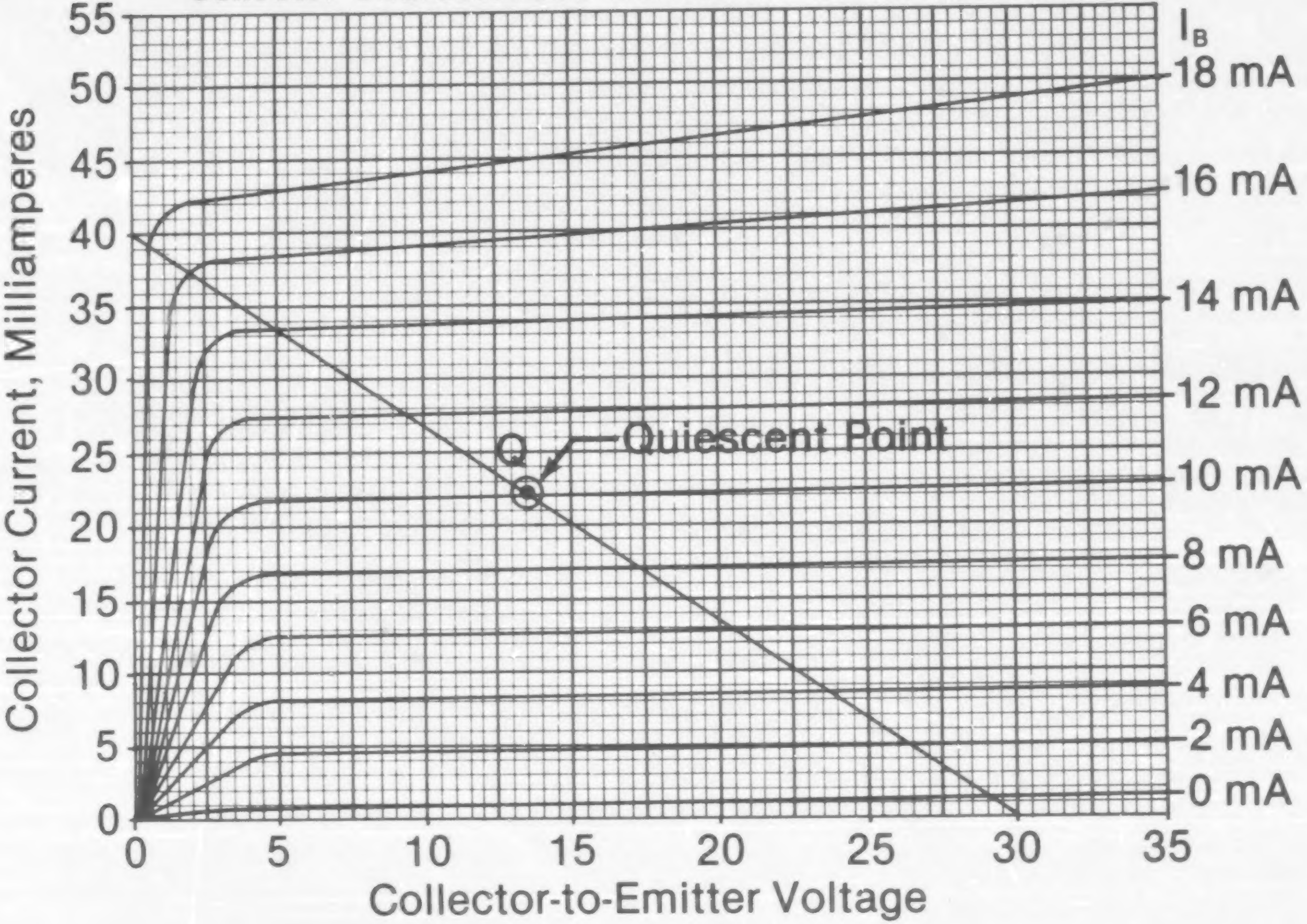


TM #2

GIE - 33-B

Quiescent Point

Collector Characteristic Curves for Transistor 2NXXX



AMPLIFIER CIRCUITS
UNIT I

ASSIGNMENT SHEET #1 — PLOT A POWER DISSIPATION CURVE, DRAW A LOAD LINE, AND LOCATE THE QUIESCENT POINT

NAME ______________________________ SCORE ____________

The information provided by a manufacturer's collector characteristic curves can be quite helpful to industrial electronics technicians. Although dissipation ratings and load lines are primarily design concerns, you may find that you will be required to use this information in troubleshooting circuit problems or in making minor modifications in electronic circuits.

Included in this assignment sheet is a collector characteristic curves graph for a hypothetical transistor 2NZZZ. This transistor has a power dissipation rating of 300 milliwatts. Use the curve information to complete the following exercises.

A. On a separate sheet of paper, calculate the collector current for each major division of collector voltage, using the formula P = IE. Use your answers to complete the chart below.

Points	Voltage (V)	Current (mA)
A	25	1. ____________
B	20	2. ____________
C	15	3. ____________
D	10	4. ____________
E	7.5	5. ____________
F	5	6. ____________

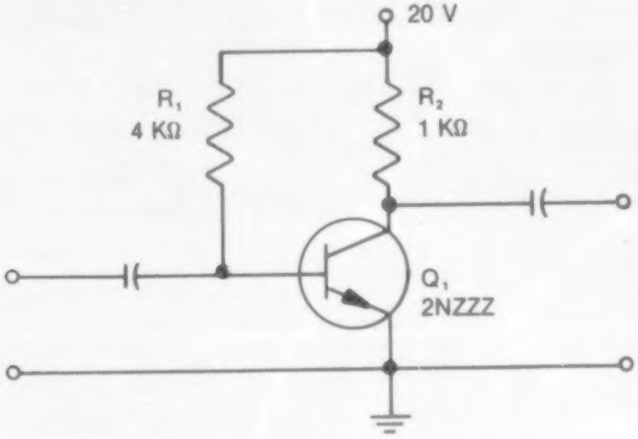
B. Plot the points on the graph and complete the power dissipation curve. Label the curve once you have plotted it.

C. Will transistor 2NZZZ operate with a collector current of 15 volts at 10 milliamperes?

____

ASSIGNMENT SHEET #1

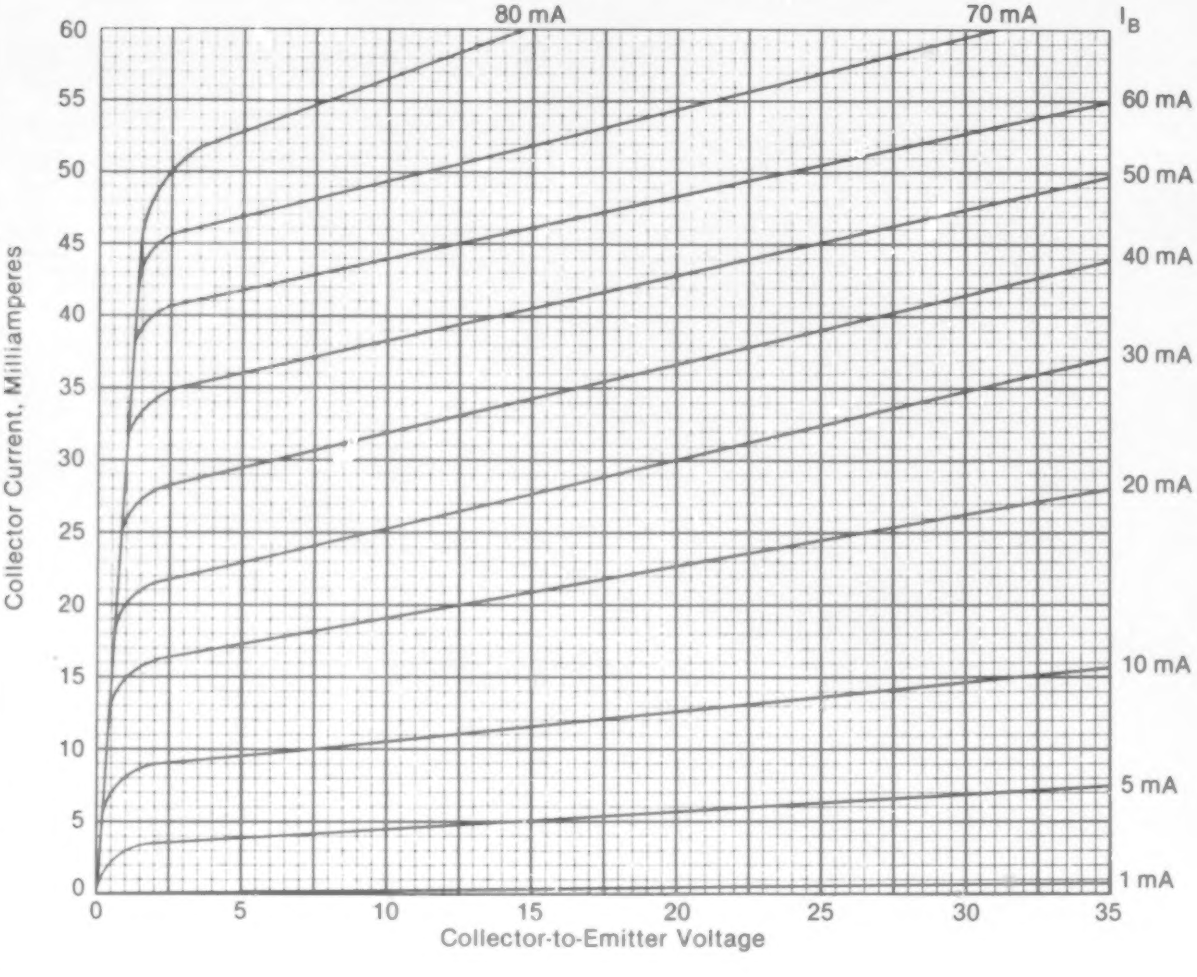
D. Assuming that the transistor is used in the amplifier circuit shown below, draw the load line for the amplifier on the graph and label it.



E. Determine the base current for the amplifier circuit shown above using the formula $I = \frac{E}{R}$, and use the base current to locate the quiescent point. Mark the point on the graph, and label the point with a Q.

ASSIGNMENT SHEET #1

Collector Characteristic Curves for Transistor 2NZZZ



GIE - 39-B

AMPLIFIER CIRCUITS
UNIT I

ASSIGNMENT SHEET #2 — STATE WHETHER POWER SHOULD BE ON OR OFF DURING VARIOUS TROUBLESHOOTING STEPS

NAME ______________________________________ SCORE ______________

Troubleshooting steps for virtually any electronic equipment are similar to those stated for amplifier circuits in Section VIII of the Information Sheet. If these procedures are not properly performed, the circuit could be damaged further, test equipment could be damaged, or the technician could be injured.

Review Section VIII, and decide which of the following steps should be performed with the power disconnected and which should be performed with the power connected. Write "off" or "on" in the blanks to indicate the power state for each step.

______A. Look for cracked or discolored printed circuit boards

______B. If signal is detected and is acceptable, continue tracing signal through to output

______C. Check transformers with ohmmeter

______D. Use tester to test transistors

______E. Use spare PCBs and replace one at a time

______F. Check power supply voltage levels

______G. Check calibration voltages at special test points marked on schematic or listed in equipment manual

______H. Look for burned components

______I. Use an oscilloscope to trace the signal, its amplification, calibration, and possible distortion as it travels from one stage to another

______J. Use ohmmeter to check for short circuits between power and ground

______K. Use an in-circuit semiconductor tester to test diodes

______L. If signal is not detected, begin tracing back through previous stages until point of signal loss is found

______M. If amplifier is removed from a system that supplies a signal, a test frequency or waveform may be injected from a signal generator connected through a capacitor for DC isolation

______N. Look for broken components

ASSIGNMENT SHEET #2

______O. Check diodes with ohmmeter

______P. Check for proper operation after each PCB is installed

______Q. Check capacitors with ohmmeter

______R. Look for loose or disconnected components

______S. Check first at center stage (of multiple-stage amplifiers) for an input signal

______T. Check inductors with ohmmeter

AMPLIFIER CIRCUITS
UNIT I

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

A.
  1. 12
  2. 15
  3. 20
  4. 30
  5. 40
  6. 60

B. See graph on next page

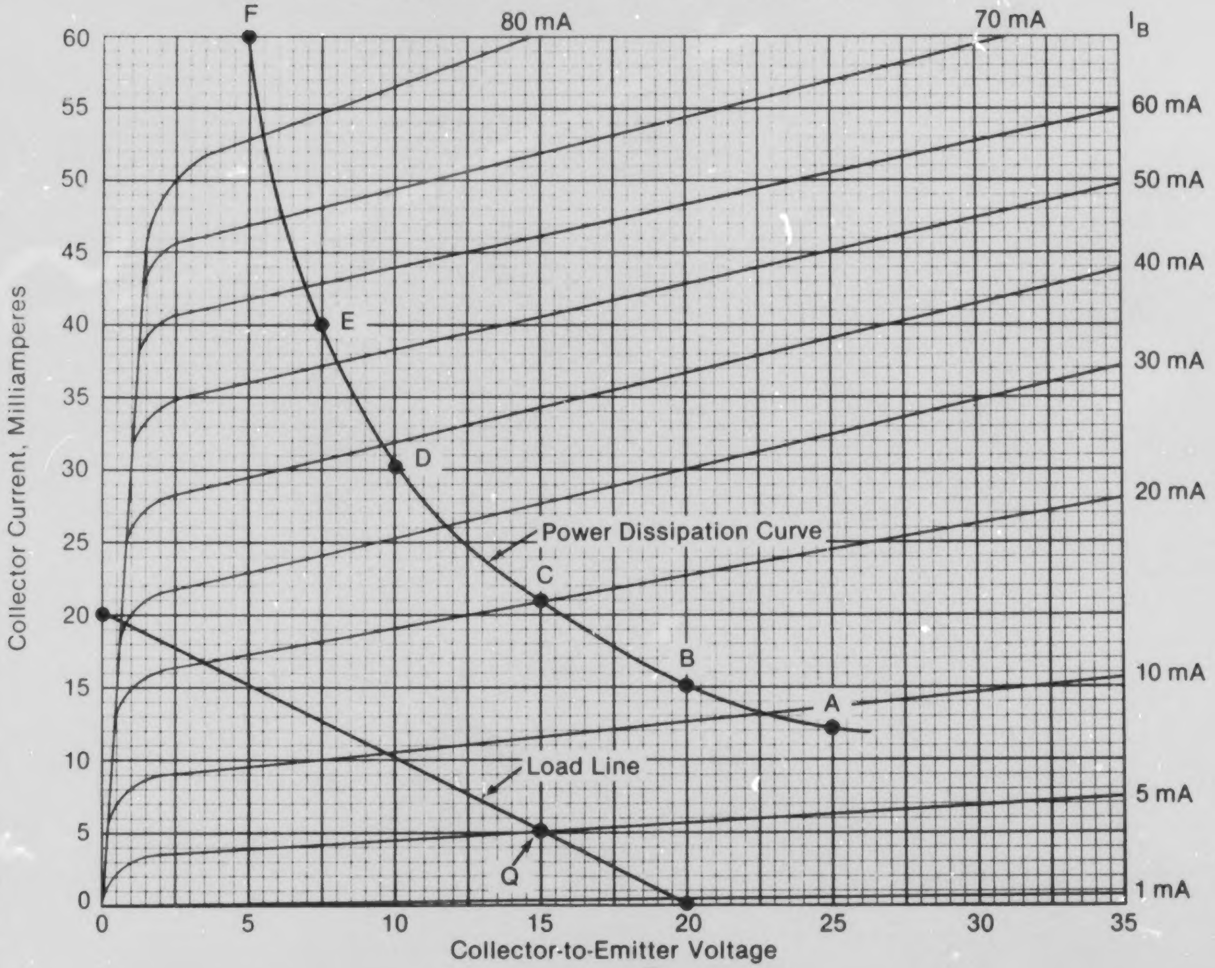
C. Yes

D. See graph on next page

E. See graph on next page

ANSWERS TO ASSIGNMENT SHEETS

Collector Characteristic Curves for Transistor 2NZZZ



ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #2

A. Off
B. On
C. Off
D. Off
E. Off
F. On
G. On
H. Off
I. On
J. Off
K. Off
L. On
M. On
N. Off
O. Off
P. On
Q. Off
R. Off
S. On
T. Off

AMPLIFIER CIRCUITS
UNIT I

JOB SHEET #1 — CONSTRUCT AND ANALYZE A COMMON-EMITTER AMPLIFIER

I. Equipment and materials

  A. Transistor, 2N3904 or equivalent

  B. Two capacitors, 10 microfarad

  C. Capacitor, 100 microfarad

  D. Resistor, 220 ohm

  E. Resistor, 3.3 kohm

  F. Two resistors, 10 kohm

  G. Resistor, 22 kohm

  H. Resistor, 100 kohm

  I. DC power supply

  J. Dual-trace oscilloscope

  K. Function generator

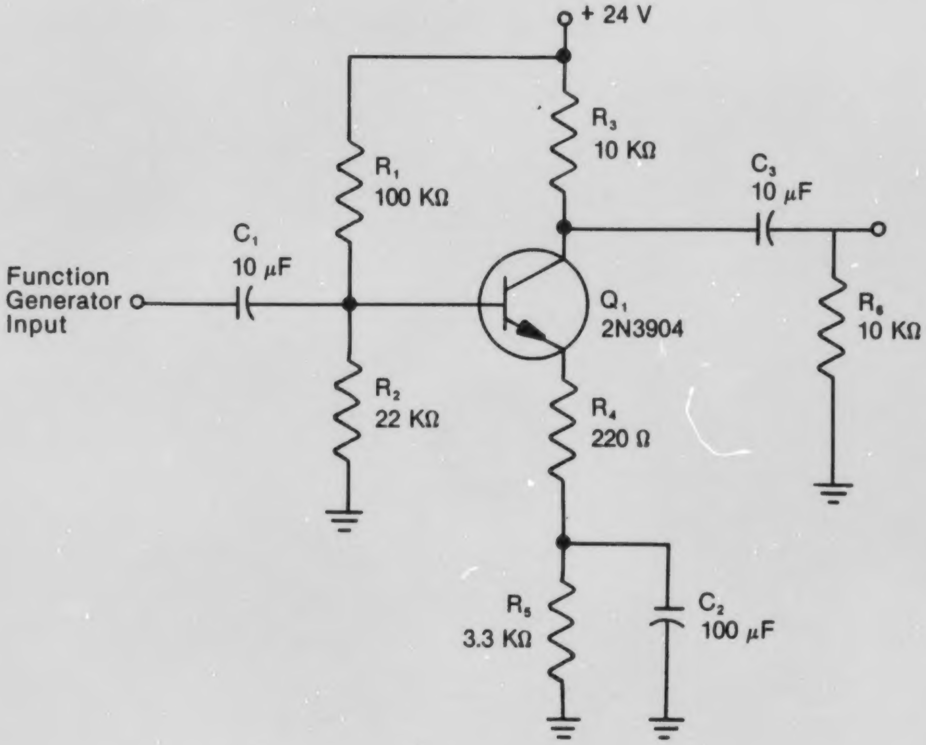
JOB SHEET #1

II. Procedure

A. Construct circuit as shown in Figure 29

(NOTE: Have the instructor check the circuit.)

FIGURE 29


+ 24 V
R_3 10 KΩ
R_1 100 KΩ
C_3 10 μF
C_1 10 μF
Function Generator Input
Q_1 2N3904
R_6 10 KΩ
R_2 22 KΩ
R_4 220 Ω
R_5 3.3 KΩ
C_2 100 μF

B. Adjust power supply for 24 volts

C. Connect function generator to input, adjusting it for a sine wave of 1 volt peak-to-peak at a frequency of 5 kilohertz

D. Connect one channel of oscilloscope to base and connect other channel to collector

E. Set oscilloscope trigger to channel connected to base

F. Observe waveforms on oscilloscope, and answer the following questions

1. Is there a phase shift between the input and output? ____________

JOB SHEET #1

2. Is there amplification of the signal? ______________________

3. Is there distortion of the signal? ______________________

G. Increase input signal voltage slowly to 6 volts peak-to-peak while observing the waveforms

H. Decrease input signal voltage until output is no longer visible

I. Continue to turn up oscilloscope sensitivity for both channels, and answer the following questions

1. Does distortion result when input voltage is high? ____________

2. Does output cease when input becomes very small? ____________

J. Return input signal to its original level and adjust DC power supply down to 5 volts while observing oscilloscope; does distortion of the waveform result?

____

K. Switch function generator to a square-wave output, and adjust oscilloscope traces for one-half cycle across screen

L. Observe pulse rise time of square wave; does amplifier respond as quickly as input rises?

____

M. Change frequency to 100 kilohertz and again observe one-half of the square-wave cycle; does the amplifier respond as quickly as the input rises?

____

(NOTE: Discuss the circuit's operation and show your answers to the instructor before you dismantle the circuit.)

N. Clean work area; put away all equipment and materials

AMPLIFIER CIRCUITS
UNIT I

JOB SHEET #2 — ANALYZE THE COMPLEMENTARY-SYMMETRY AMPLIFIER

I. Equipment and materials

   A. Dual-trace oscilloscope

   B. DC power supply

   C. Function generator

   D. Two transistors, 2N3904 or equivalent

   E. Transistor, 2N1305 or equivalent

   F. Potentiometer, 500 kohm

   G. Potentiometer, 10 kohm

   H. Two capacitors, 50 microfarad

   I. Three resistors, 100 ohm

   J. Resistor, 1 kohm

   K. Resistor, 4.7 kohm

   L. Resistor, 47 kohm

   M. Resistor, 100 kohm

   N. Breadboard

   O. Various test leads

   P. Audio speaker

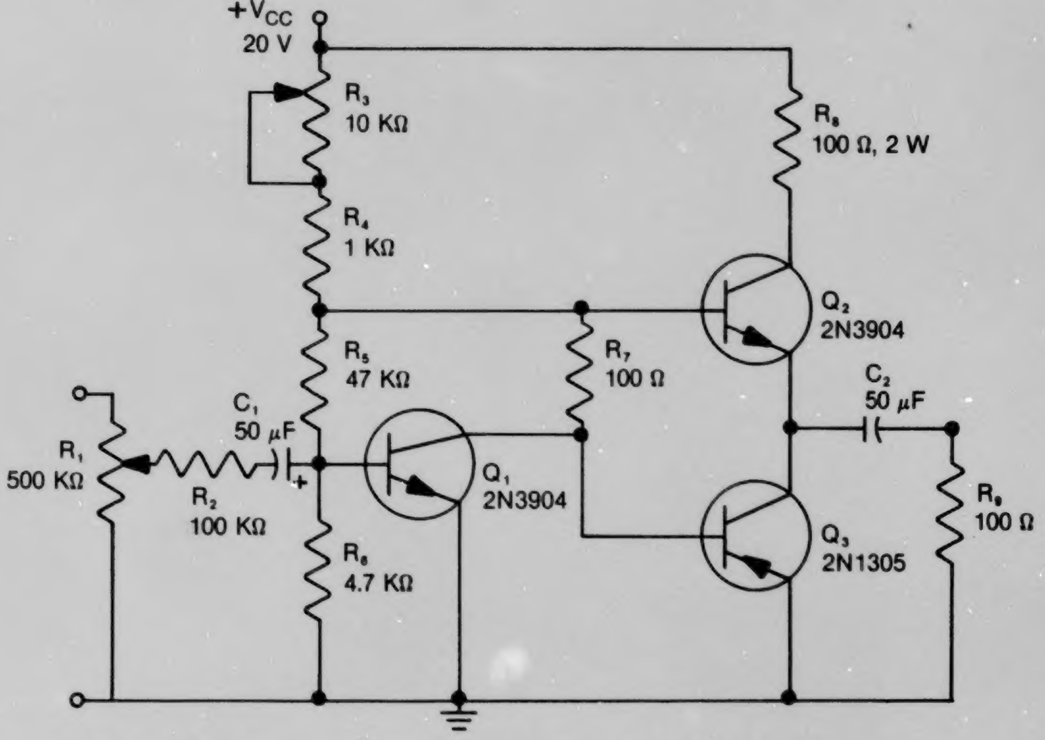
JOB SHEET #2

II. Procedure

A. Construct circuit as shown in Figure 30

(NOTE: Before applying power to circuit, be sure R1 is set for a minimum input signal, and R3 is set for maximum resistance. Have the instructor check the circuit.)

FIGURE 30


$+V_{CC}$
20 V
R_3
10 KΩ
R_8
100 Ω, 2 W
R_4
1 KΩ
Q_2
2N3904
R_5
47 KΩ
R_7
100 Ω
C_2
50 μF
C_1
50 μF
R_1
500 KΩ
R_2
100 KΩ
+
Q_1
2N3904
R_9
100 Ω
Q_3
2N1305
R_6
4.7 KΩ

B. Adjust function generator for an output signal of 5 VAC at a frequency of 1 kilohertz

(NOTE: Be sure the V_{CC} power supply is turned on before applying the input signal.)

C. Connect function generator to amplifier circuit input

D. Connect oscilloscope across output resistor, R9

E. Adjust R1 for an output signal of 1 volt rms

JOB SHEET #2

F. Check for any visible distortion on output signal

(NOTE: If distortion is visible, proceed to step I.)

G. If no distortion is visible, adjust R1 until distortion appears on output signal

H. Slowly adjust potentiometer R3 until distortion just disappears

(NOTE: Do not vary R3 too quickly, or collector current may become excessive.)

I. Connect other oscilloscope channel to input

J. Vary frequency of input over a wide range while adjusting function generator output amplitude control, if necessary, to keep the input amplitude constant

K. Observe output amplitude as frequency changes, and check for a noticeable change in amplitude

(NOTE: Frequency response of an amplifier is a measure of its ability to amplify a range of frequencies without varying the amplification significantly.)

L. Connect speaker across output; adjust frequency of function generator to 5 kilohertz

M. Adjust R1 while listening to volume of speaker and observing output on oscilloscope

Is volume dependent upon amplitude? ______________________________

(NOTE: The human ear does not hear volume directly proportional to amplitude. For this reason, OSHA regulations for industry recognize an adjusted scale of noise volume called the dBA scale. Industrial technicians working in plants where noise levels are high may be required to measure, record, and control noise levels in order to protect employees from hearing loss.)

N. Vary potentiometer R3 while observing output waveform and listening to speaker

Does distortion result? ______________________________

Yes

Can you hear the distortion? ______________________________

O. Readjust R3 to point where distortion ceases

JOB SHEET #2

P. Connect a jumper across R7 while listening to speaker and observing waveform

(NOTE: Distortion results from nonlinearity of the bias of Q2 and Q3 when R3 and R7 are not properly sized. Show your answers to your instructor and discuss your results before you dismantle the circuit.)

Q. Clean work area; put away equipment and materials

AMPLIFIER CIRCUITS
UNIT I

JOB SHEET #3 — TROUBLESHOOT A COMMON-EMITTER AMPLIFIER

I. Equipment and materials

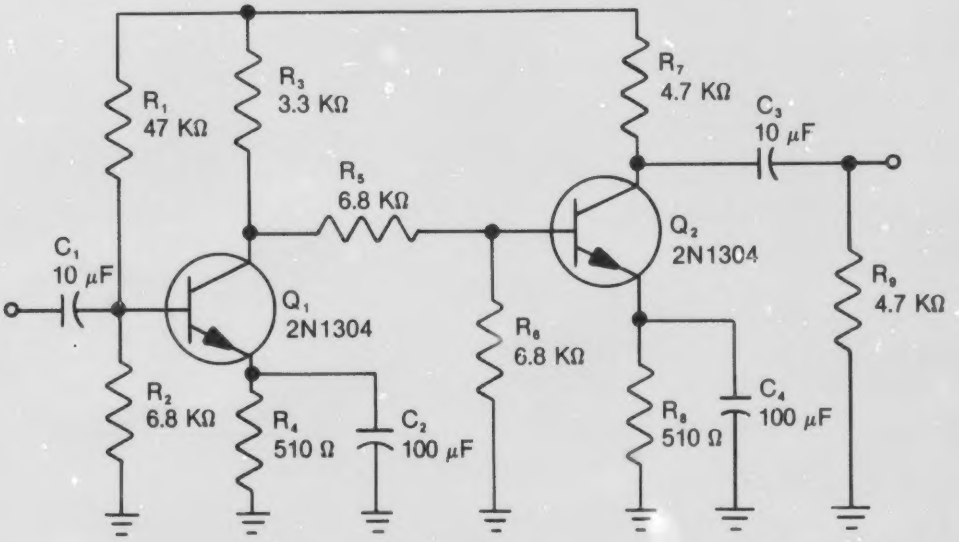
- A. Oscilloscope
- B. Function generator
- C. In-circuit transistor tester
- D. DC power supply (0 to 20 volts)
- E. Faulty components (provided by instructor)
- F. Two transistors, 2N1304
- G. Two capacitors, 10 microfarad
- H. Two capacitors, 100 microfarad
- I. Resistor, 47 kohm
- J. Three resistors, 6.8 kohm
- K. Two resistors, 4.7 kohm
- L. Resistor, 3.3 kohm
- M. Two resistors, 510 ohm

JOB SHEET #3

II. Procedure

A. Construct circuit as shown in Figure 31

FIGURE 31


R1
47 KΩ
R3
3.3 KΩ
R7
4.7 KΩ
C3
10 μF
R5
6.8 KΩ
C1
10 μF
Q1
2N1304
Q2
2N1304
R9
4.7 KΩ
R6
6.8 KΩ
R2
6.8 KΩ
R4
510 Ω
C2
100 μF
R8
510 Ω
C4
100 μF

B. Connect oscilloscope and function generator to circuit

C. Use troubleshooting steps outlined in Information Sheet, Section VII to troubleshoot the circuit

D. Use Ohm's law to calculate currents and voltages of circuit

E. Compare currents and voltages to multimeter readings

(NOTE: If you believe that you have isolated the defective component, ask the instructor if you are correct, and ask for a replacement.)

F. Replace the defective component, and see if circuit functions properly

G. If circuit still does not operate, repeat troubleshooting procedure

(NOTE: After the circuit is operating properly, ask the instructor to check it.)

H. Clean work area; put away equipment and materials

AMPLIFIER CIRCUITS
UNIT I

TEST

NAME ____ SCORE ________________

1. Match terms associated with amplifier circuits to their correct definitions. Write the correct numbers in the blanks.

______a. Point on the characteristic curves graph of an amplifier; represents the conditions that exist when the input signal is not applied

______b. Method of connecting signals between stages or circuits

______c. Power output 0.707 of peak power

______d. Ratio of output to input

______e. Circuit containing one or more active devices controlled by a voltage or current input that alters the power or waveform of the output

______f. Undesirable changes in output signal

______g. Conversion of information into electronic signals

______h. Section of circuitry

______i. State when all normal charge carriers are flowing in a device

______j. State when all normal charge carriers stop flowing in a device

______k. Electron tube or solid-state component capable of controlling relatively large values of output power with a small power input

______l. Range of frequencies between half-power points

______m. Process of routing a portion of a circuit's output power back to its input in order to provide control

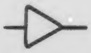
______n. Continuous signal varying in amplitude as contrasted to digital signals, which vary in frequency and position of pulses

1. Gain
2. Amplifier
3. Distortion
4. Active device
5. Analog signal
6. Bandwidth
7. Half-power point
8. Feedback
9. Stage
10. Modulation
11. Quiescent point
12. Coupling
13. Cutoff
14. Saturation

TEST

2. Match symbols and abbreviations associated with amplifier circuits to their correct interpetations. Write the correct numbers in the blanks.

_____a. Amplifier symbol
_____b. Amperes
_____c. Load resistor
_____d. Occupational Safety and Health Administration
_____e. Metal-oxide semiconductor
_____f. Bandwidth
_____g. Integrated circuit
_____h. Transistor
_____i. Inductive/capacitive circuit
_____j. A-scale decibels
_____k. Greek letter beta; designates current gain
_____l. Schematic designator for a transistor
_____m. Collector current
_____n. Transformer
_____o. Total resistance
_____p. Resistive/capacitive circuit
_____q. Collector supply voltage
_____r. Ohm
_____s. Single-pole, single-throw switch
_____t. Insulated gate, field-effect transistor
_____u. Amplifier
_____v. Base current

1. XSTR
2. Bw
3. IC
4. Q
5. R_t
6. MOS
7. R_t
8. XFMR
9. A, amp
10. RC
11. OSHA
12. V_{CC}
13. 
14. I_C
15. B
16. dBA
17. LC
18. SPST
19. Ω
20. IGFET
21. AMP
22. I_B

TEST

3. Match types of amplifiers to their correct uses. Write the correct numbers in the blanks.

______a. Used to produce square waveforms for digital circuits from waveforms that may be rounded due to previous distortion

______b. Used to isolate one circuit from another to reduce interference or loading of previous circuit

______c. Used to combine two frequencies

______d. Used to convert an analog signal into a pulse-frequency modulated signal by switching on and off at a frequency higher than the input frequency

______e. Used to boost input power sufficiently so that following circuitry can operate effectively

______f. Used in circuits where low distortion is required

______g. Used for a variety of circuit applications including use as multiplier, divider, summer, integrator, differentiator, amplifier, and comparator

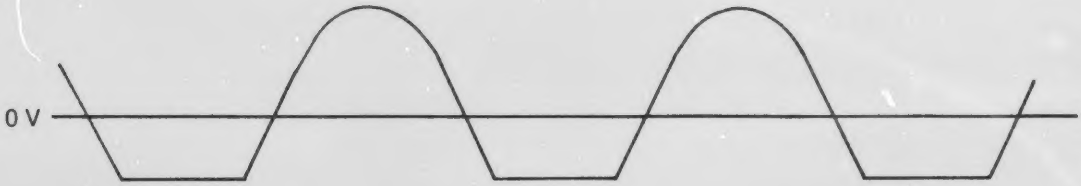
______h. Used to produce large amounts of power in order to drive an output device such as a servomotor or speaker

1. Operational amplifier (op-amp)
2. Preamplifier (pre-amp)
3. Power amplifier
4. Chopper amplifier
5. Squaring amplifier
6. Buffer amplifier (buffer amp)
7. Mixer amplifier
8. Linear amplifier

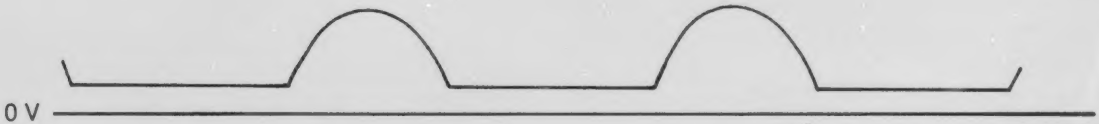
TEST

4. Identify the following classes of amplification. Write the correct names in the blanks.

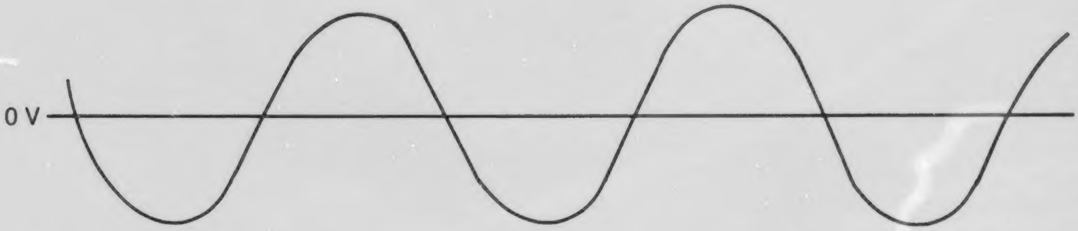
Class C
Class A
Class B
Class AB



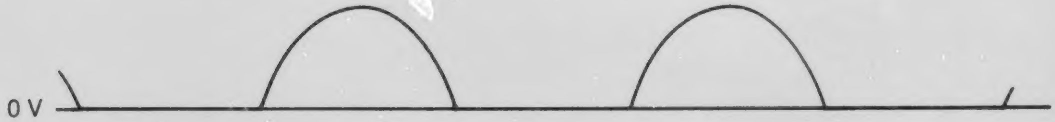
a. ____



b. ____



c. ____

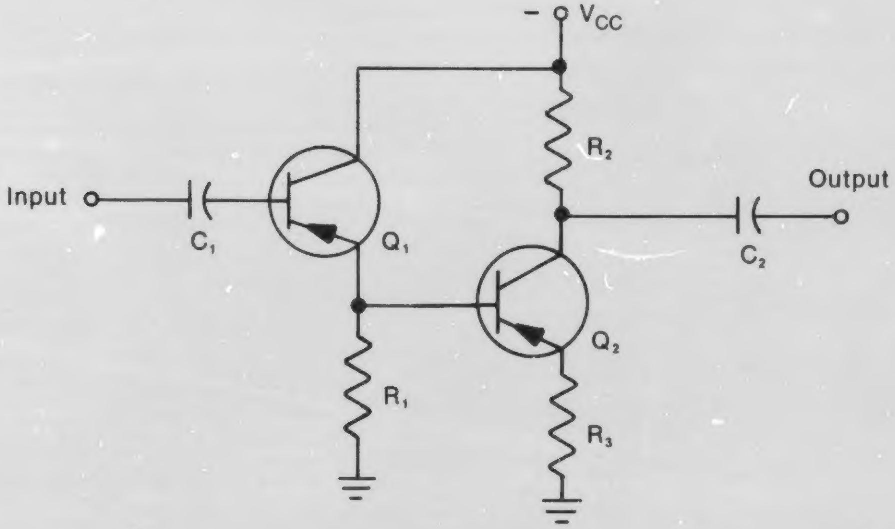


d. ____

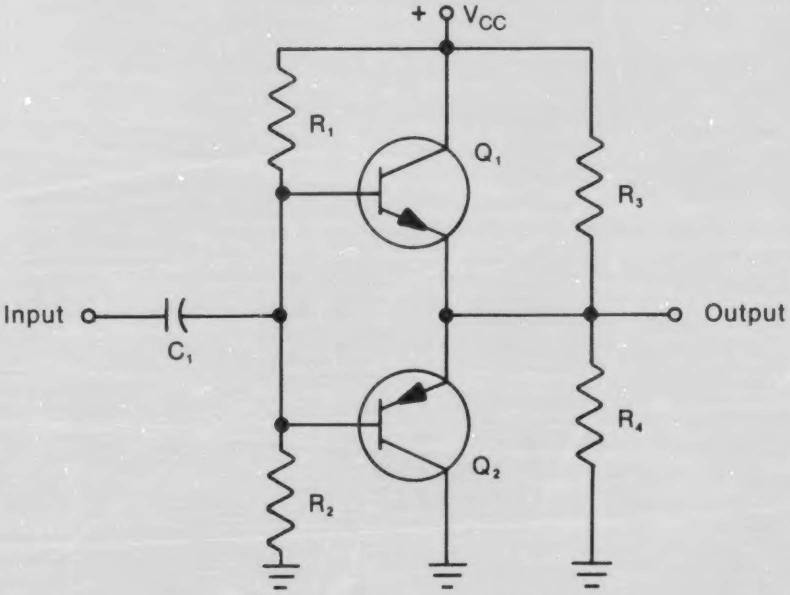
TEST

5. Identify the following amplifier circuits. Write the correct names in the blanks.

Cascode
Common-emitter
Darlington
Common-collector
Complementary-symmetry
Common-base
Differential
Push-pull
Cascade (direct-coupled)

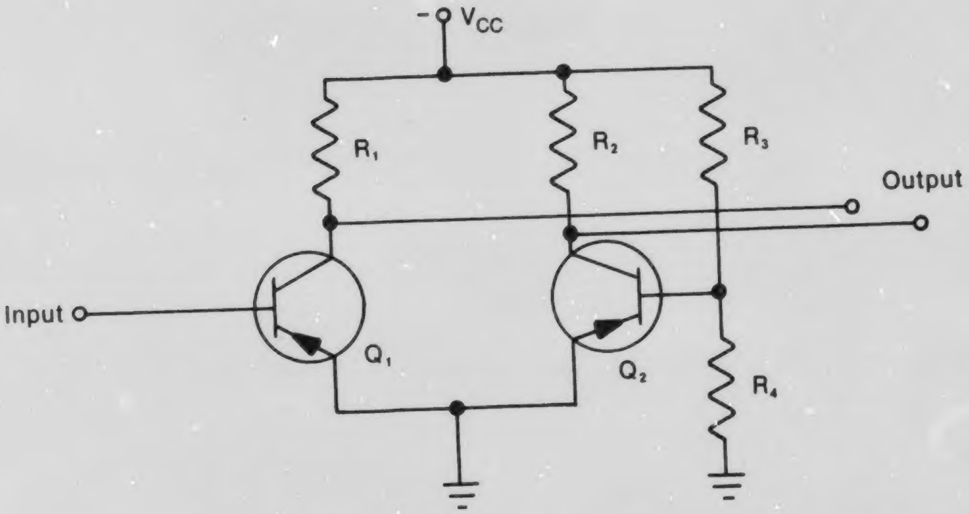

− V_{CC}
R_2
Output
Input
C_1
Q_1
C_2
Q_2
R_1
R_3

a. ______________________________

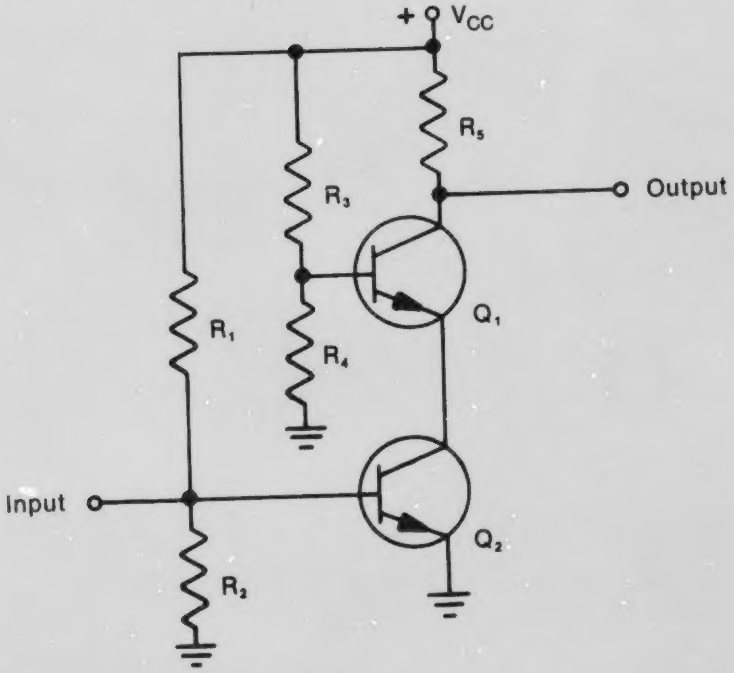

+ V_{CC}
R_1
Q_1
R_3
Input
Output
C_1
R_4
Q_2
R_2

b. ______________________________

TEST

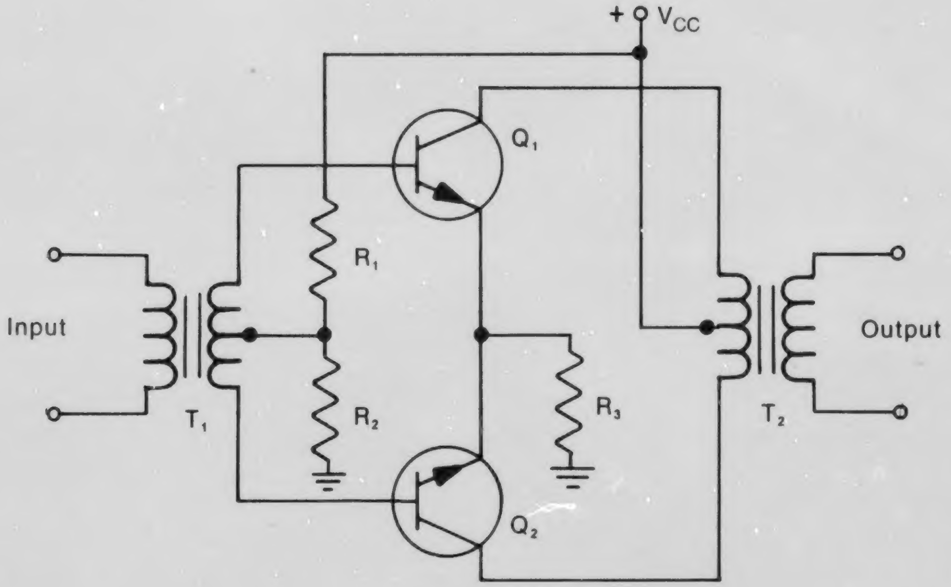

- VCC
R1
R2
R3
Output
Input
Q1
Q2
R4

c. ______________________________

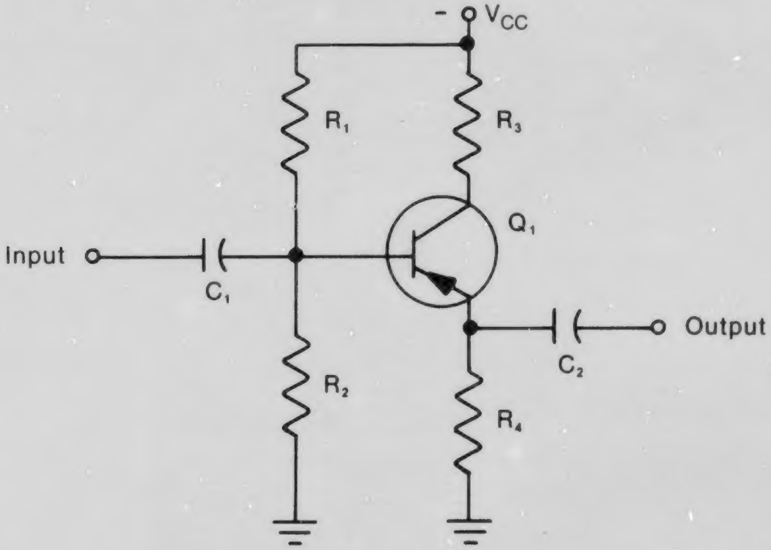

+ VCC
R5
Output
R3
Q1
R1
R4
Input
Q2
R2

d. ______________________________

TEST

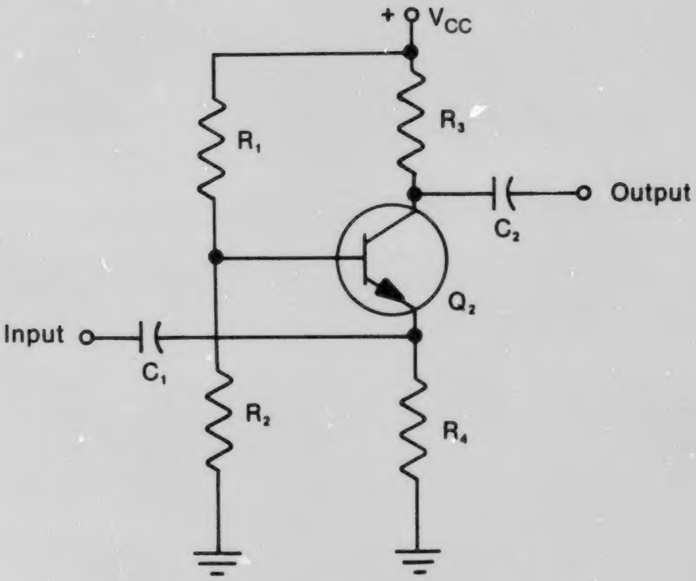

+ VCC
Q1
Q2
R1
R2
R3
T1
T2
Input
Output

e. ______________________________

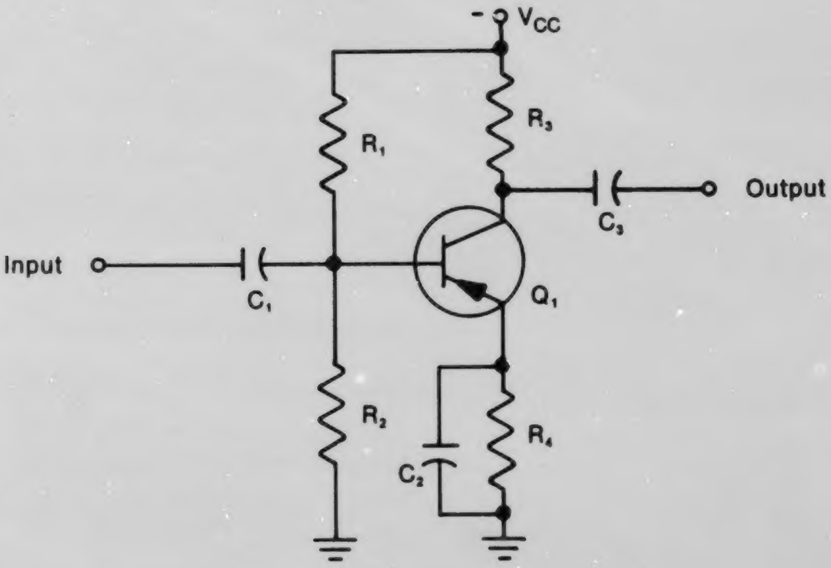

- VCC
R1
R2
R3
R4
Q1
C1
C2
Input
Output

f. ______________________________

TEST

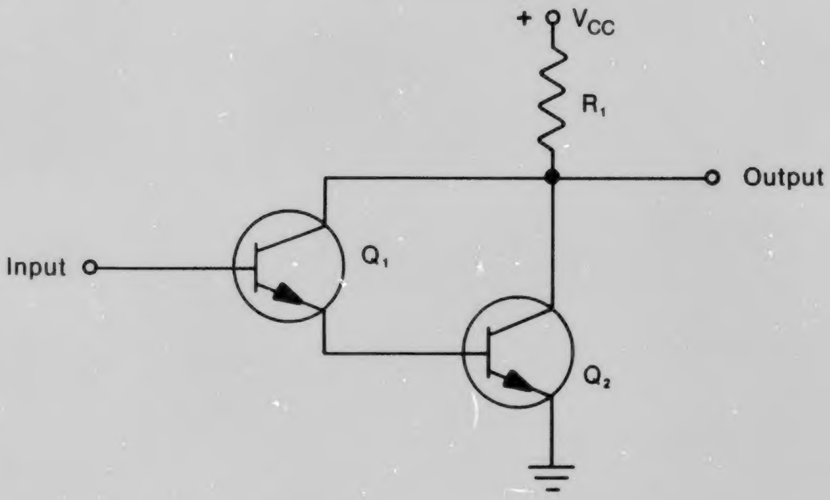

+ V$_{CC}$
R$_1$
R$_3$
Output
C$_2$
Q$_2$
Input
C$_1$
R$_2$
R$_4$

g. ______________________________


- V$_{CC}$
R$_1$
R$_3$
Output
C$_3$
Input
C$_1$
Q$_1$
R$_2$
R$_4$
C$_2$

h. ______________________________

TEST



i. ______________________________

6. Match amplifier coupling techniques to their correct characteristics. Write the correct numbers in the blanks. Characteristics are continued on the following page.

_____a. Couples AC and DC, but provides some isolation between stages; provides for base biasing by DC from the previous stage

_____b. Allows for DC coupling; reduces cost by eliminating components; allows bias interference between stages

_____c. Blocks DC; impedes surges

_____d. Blocks DC; allows instant coupling of sharp-rise time pulses

_____e. Provides complete isolation between stages; couples very low frequencies

_____f. Allows for passing or blocking one range of frequencies; can be an LC coupling (inductor and capacitor) or a transformer and capacitor coupling

_____g. Blocks DC in one direction and rectifies AC in one direction; can be used to direct positives or negatives to particular circuits

1. Capacitor
2. Transformer
3. Optical
4. Diode
5. RC (resistor and capacitor)
6. Direct
7. Inductive
8. Resistor
9. Tuned

TEST

______h. Provides for DC coupling; provides for coupling fast-changing signals

______i. Seldom used as a single component; allows DC but impedes high frequency or rapid changes

7. Calculate the current gain of a Darlington amplifier. The amplifier has two transistors. One transistor has a beta of 30 and the other has a beta of 15. Show your work.

   Current gain = ____

8. List steps for troubleshooting amplifier circuits.

   a. ____

      1) Look for burned components — Power off

      2) Look for broken components — Power off

      3) Look for loose or disconnected components — Power off

      4) Look for cracked or discolored printed circuit boards — Power off

   b. ____

      1) Check power supply voltage levels — Power on

      2) Check calibration voltages at special test points marked on schematic or listed in equipment manual — Power on

   c. ____

      1) Check first at center stage (of multiple-stage amplifiers) for an input signal — Power on

      2) If signal is detected and is acceptable, continue tracing signal through to output — Power on

TEST

3) If signal is not detected, begin tracing back through previous stages until point of signal loss is found — Power on

4) If amplifier is removed from a system that supplies a signal, a test frequency or waveform may be injected from a signal generator connected through a capacitor for DC isolation — Power on

5) Use oscilloscope to trace signal, its amplification, calibration, and possible distortion as it travels from one stage to another — Power on

d. ____

1) Check for short circuits between power and ground — Power off

2) Check diodes — Power off

3) Check capacitors — Power off

4) Check transformers — Power off

5) Check inductors — Power off

e. ____

1) Use in-circuit semiconductor tester to test diodes — Power off

2) Use tester to test transistors — Power off

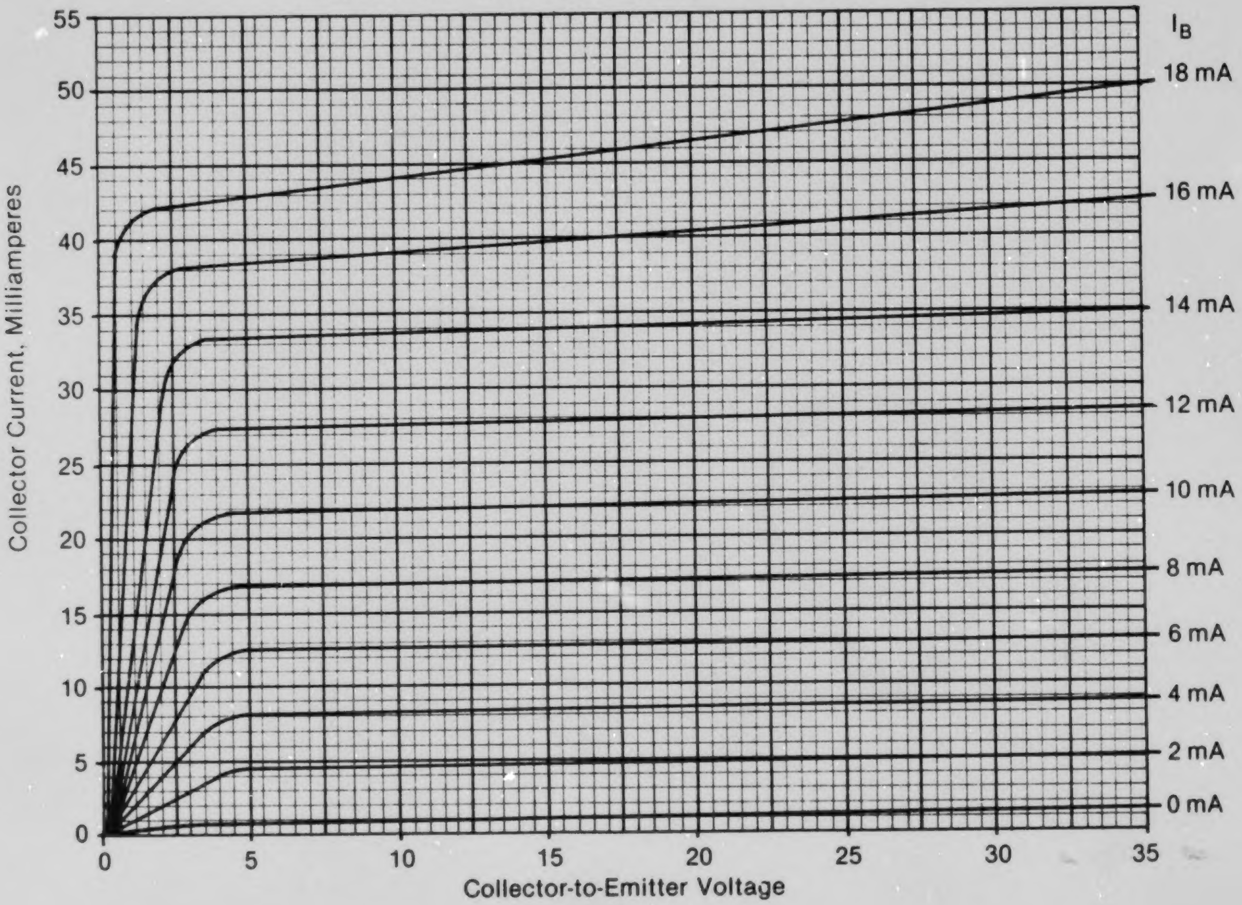
f. ____

1) Use spare PCBs, and replace one at a time — Power off

2) Check for proper operation after each PCB is installed — Power on

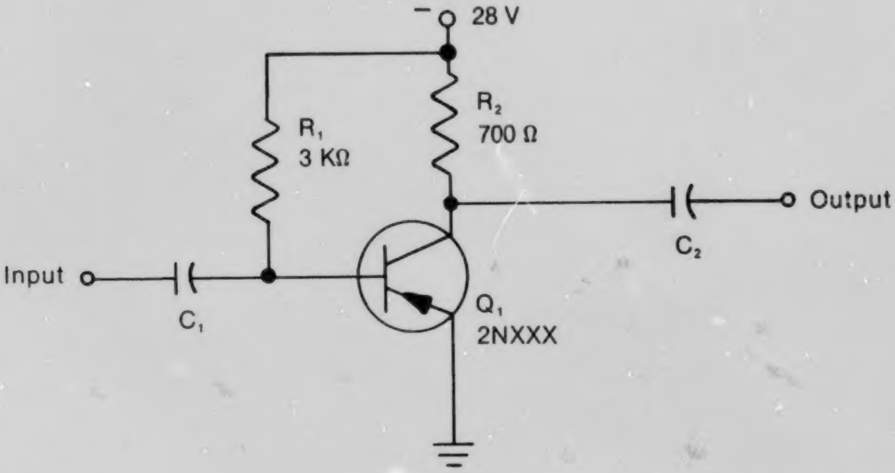
9. Plot a transistor power dissipation curve on the following graph. Assume that the transistor has a power dissipation of 180 milliwatts.

Collector Characteristic Curves for Transistor 2NXXX



TEST

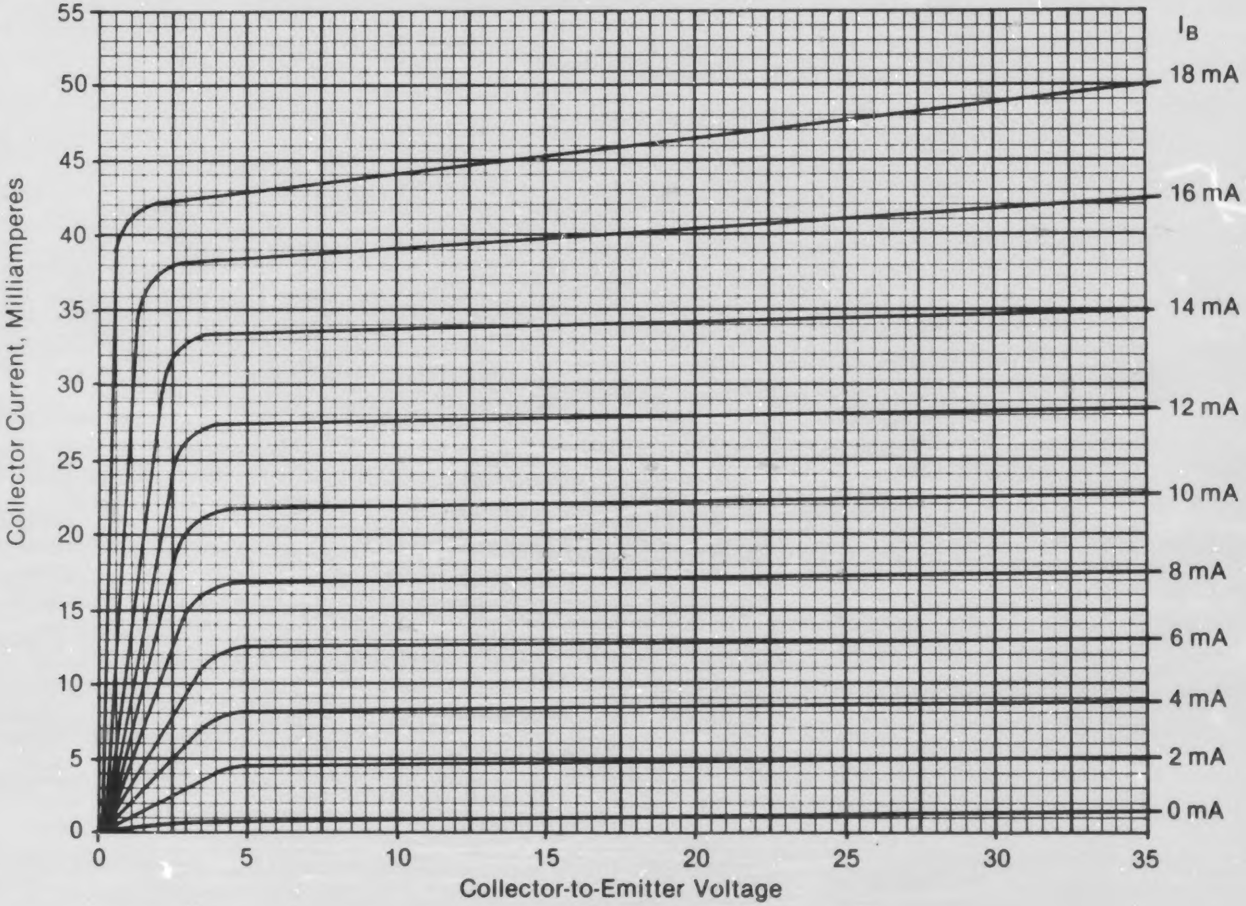
10. Draw a transistor load line on the graph on the following page for a single-stage amplifier as shown in the schematic below.


- 28 V
R$_1$
3 KΩ
R$_2$
700 Ω
Output
C$_2$
Input
C$_1$
Q$_1$
2NXXX

70-B

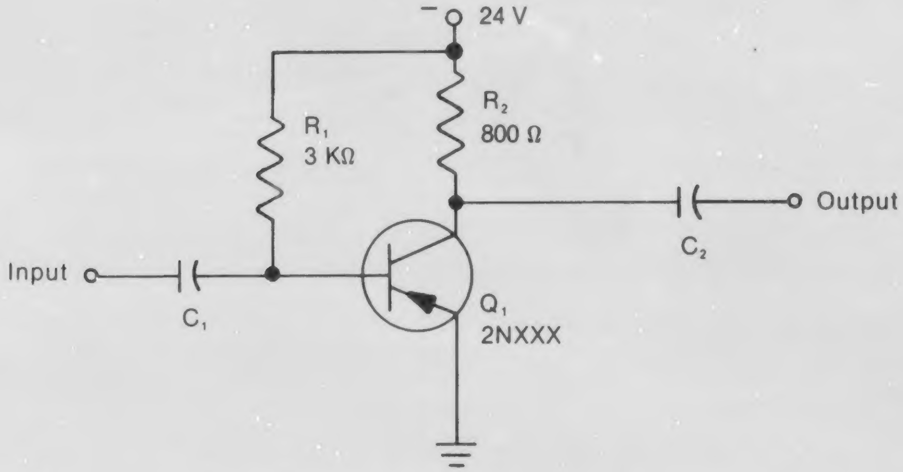
TEST

Collector Characteristic Curves for Transistor 2NXXX



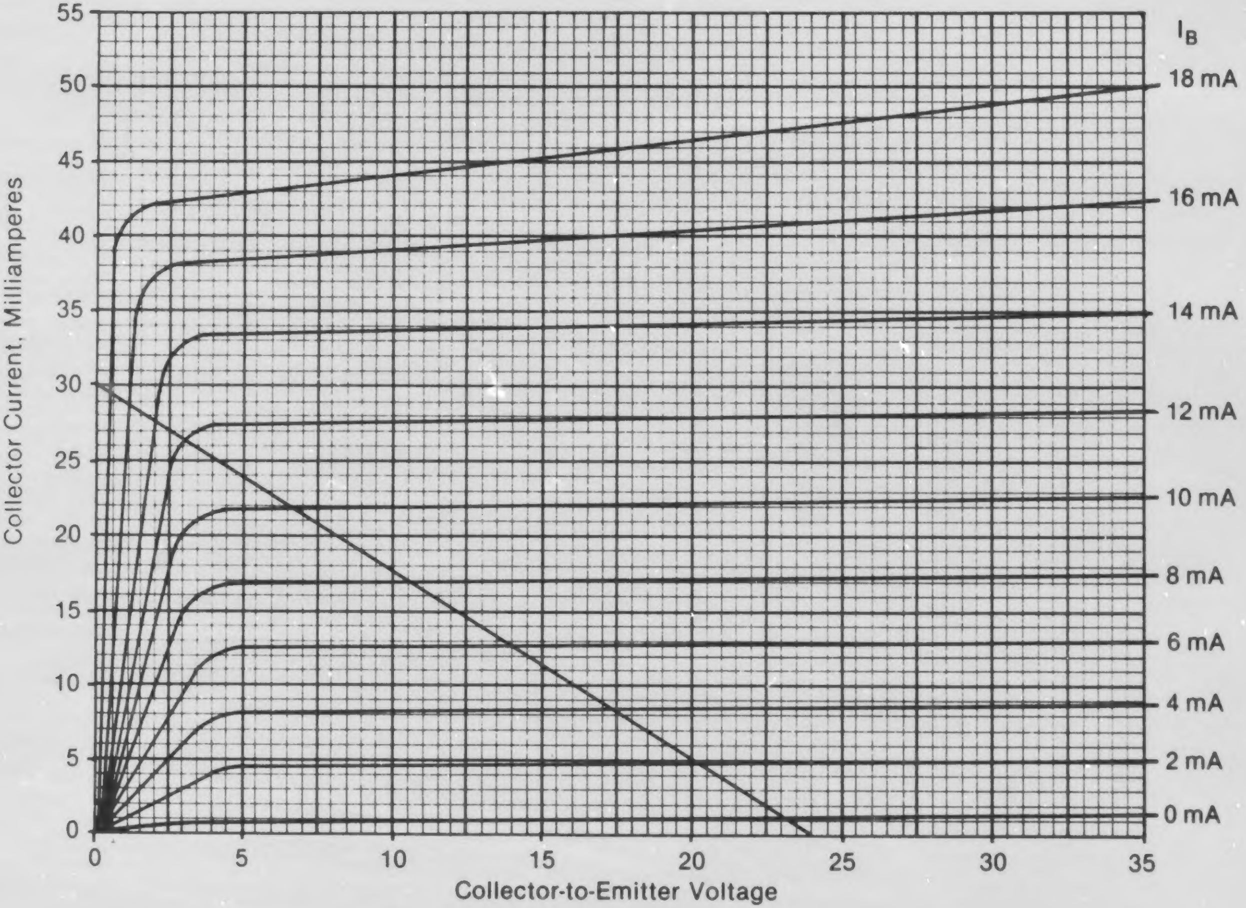
TEST

11. Locate the quiescent point on the transistor load line on the graph on the following page for the circuit shown in the schematic below.


– 24 V
R₂
800 Ω
R₁
3 KΩ
Input
C₁
Output
C₂
Q₁
2NXXX

TEST

Collector Characteristic Curves for Transistor 2NXXX



72-B

TEST

(NOTE: Test questions 12 and 13 list the assignment and job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

12. State whether power should be on or off during various troubleshooting steps.

13. Demonstrate the ability to

    a. Construct and analyze a common-emitter amplifier.

    b. Analyze the complementary-symmetry amplifier.

    c. Troubleshoot a common-emitter amplifier.

AMPLIFIER CIRCUITS
UNIT I

ANSWERS TO TEST

1.

a.	11	f.	3	k.	4
b.	12	g.	10	l.	6
c.	7	h.	9	m.	8
d.	1	i.	14	n.	5
e.	2	j.	13		

2.

a.	13	g.	3	m.	14	s.	18
b.	9	h.	1	n.	8	t.	20
c.	7	i.	17	o.	5	u.	21
d.	11	j.	16	p.	10	v.	22
e.	6	k.	15	q.	12		
f.	2	l.	4	r.	19		

3.

a.	5	e.	2
b.	6	f.	8
c.	7	g.	1
d.	4	h.	3

4. a. Class AB
   b. Class C
   c. Class A
   d. Class B

ANSWERS TO TEST

5. a. Cascade (direct-coupled)
   b. Complementary-symmetry
   c. Differential
   d. Cascode
   e. Push-pull
   f. Common-collector
   g. Common-base
   h. Common-emitter
   i. Darlington

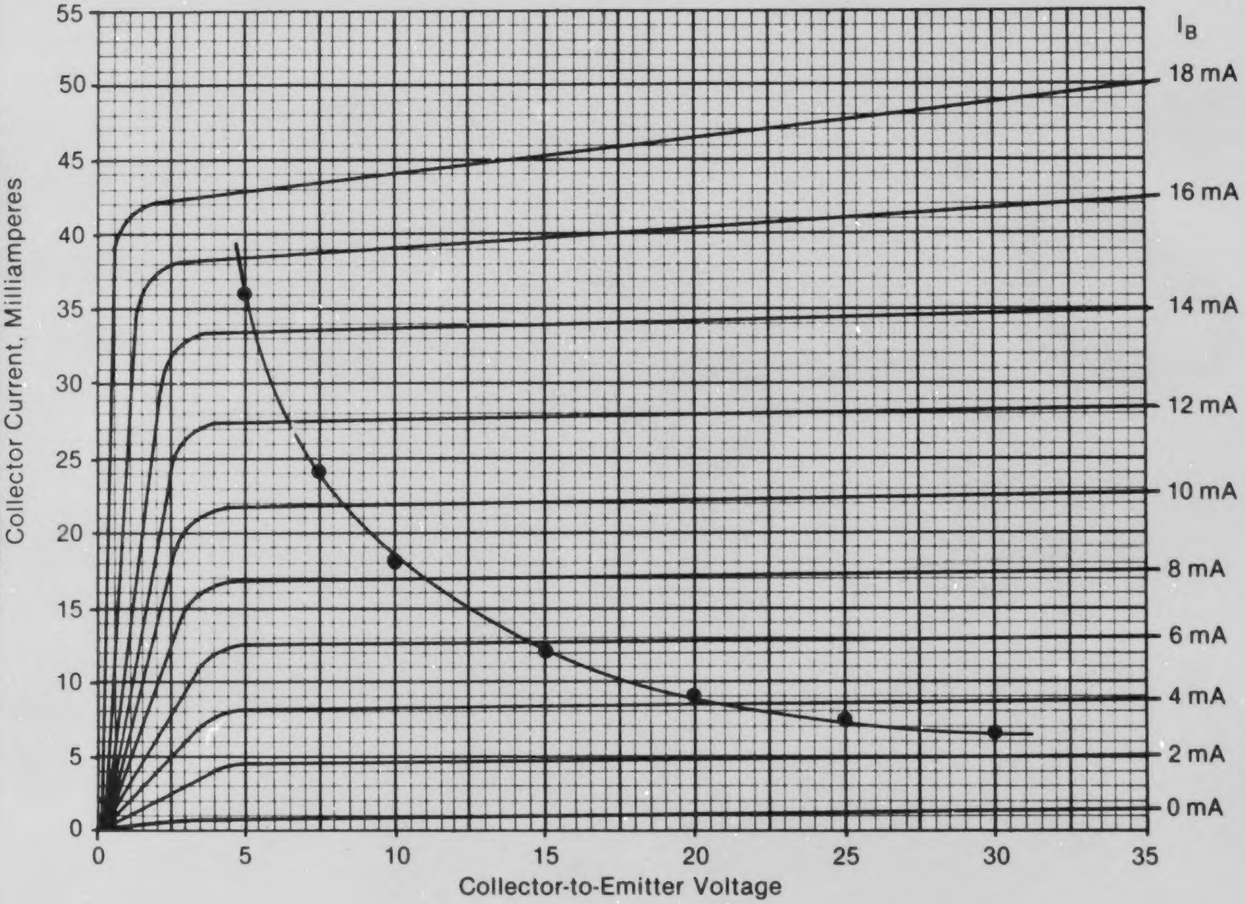
6. a. 8
   b. 6
   c. 2
   d. 1
   e. 3
   f. 9
   g. 4
   h. 5
   i. 7

7. 450

8. a. Make visual circuit inspection
   b. Make voltage checks
   c. Trace signals
   d. Make ohmmeter checks
   e. Test diodes and transistors
   f. Substitute components

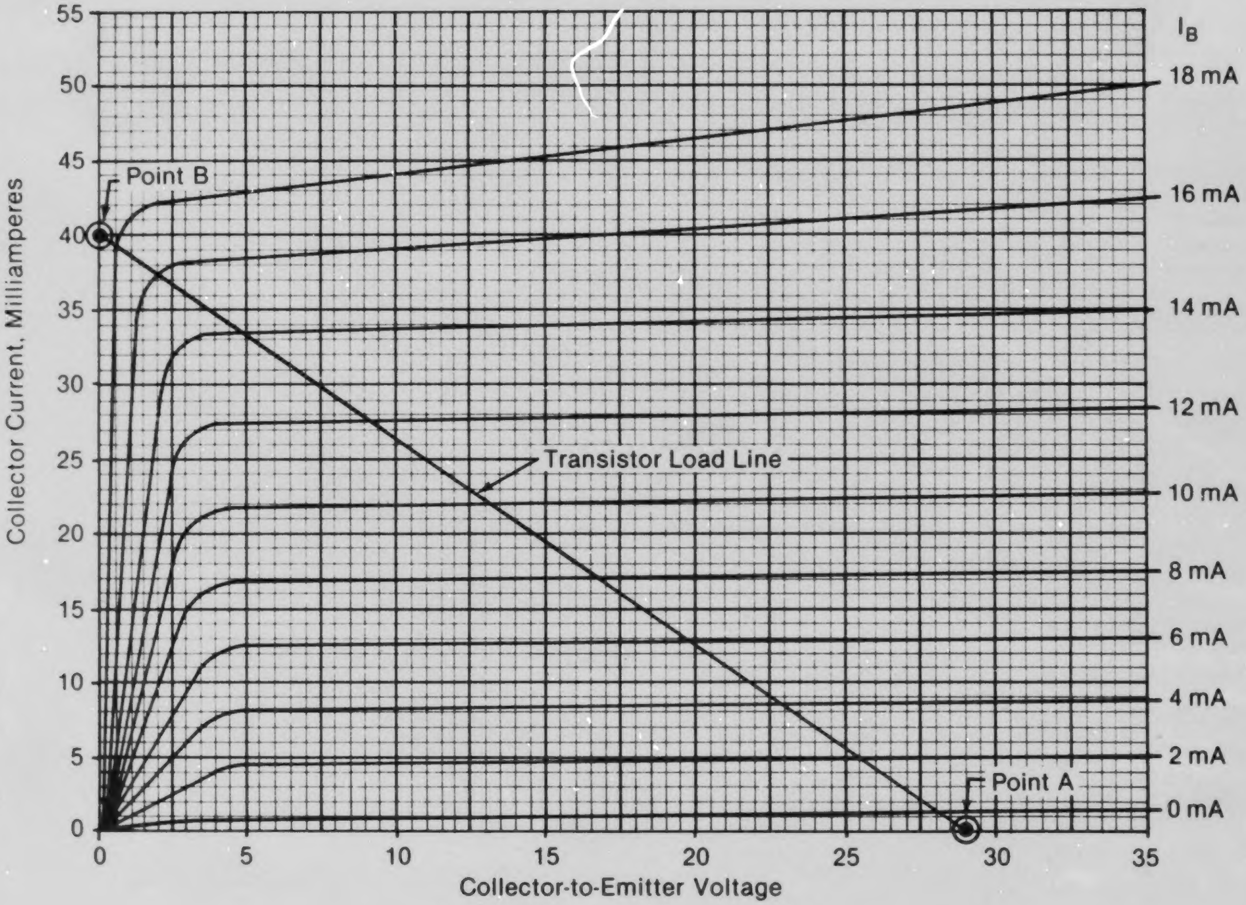
ANSWERS TO TEST

Collector Characteristic Curves for Transistor 2NXXX



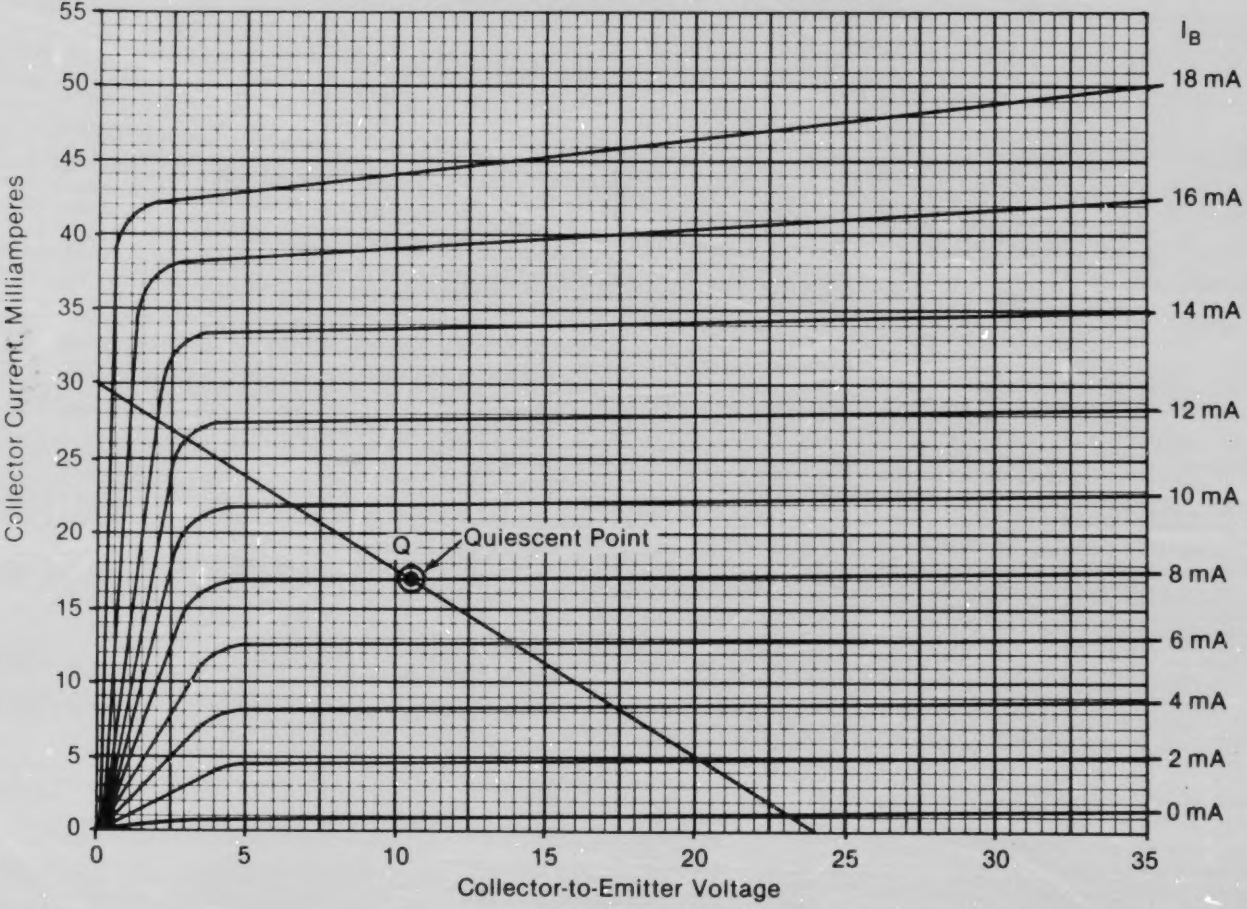
ANSWERS TO TEST

Collector Characteristic Curves for Transistor 2NXXX



ANSWERS TO TEST

Collector Characteristic Curves for Transistor 2NXXX



ANSWERS TO TEST

12. Evaluated to the satisfaction of the instructor

13. Performance skills evaluated to the satisfaction of the instructor

POWER SUPPLY CIRCUITS
UNIT II

UNIT OBJECTIVE

After completing this unit, the student should be able to construct and analyze power supply circuits. The student will show this knowledge by completing assignment sheets, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with power supplies to their correct definitions.
2. Interpret abbreviations associated with power supply circuits.
3. Identify common power supply symbols.
4. Name the primary energy sources for power supplies.
5. Match types of electrical power supplies to their correct applications.
6. Match types of inverters to their correct uses.
7. Match power supply components to their correct applications.
8. Match basic power supply functions to their correct descriptions.
9. Label various rectifier circuits.
10. Match diode output waveforms to their correct diode circuits.
11. Label voltage regulator circuit schematics.
12. Name integrated circuit regulators.
13. Label power supply circuit schematics.
14. Demonstrate the ability to
    a. Analyze DC to DC power supply.
    b. Analyze an AC to DC half-wave voltage doubler.
    c. Analyze an AC to DC full-wave voltage doubler.
    d. Analyze an AC to DC selenium rectifier circuit.

OBJECTIVE SHEET

e. Analyze the operation of a bridge rectifier.

f. Construct a silicon-controlled rectifier power circuit.

g. Construct a Triac power circuit.

POWER SUPPLY CIRCUITS
UNIT II

SUGGESTED ACTIVITIES

I. Suggested activities

  A. Make transparencies.

  B. Provide students with objective sheet.

  C. Discuss unit and specific objectives.

  D. Provide students with information, assignment, and job sheets.

  E. Discuss information and assignment sheets.

  F. Demonstrate and discuss procedures outlined in job sheets.

  G. Demonstrate various power supply configurations of rectifiers, filters, and so on.

  H. Give test.

  I. Reteach and retest if necessary.

II. Instructional materials

  A. Objective sheet

  B. Suggested activities

  C. Information sheet

  D. Transparency masters

    1. TM #1 — DC to AC Inverters

    2. TM #2 — Simple Regulated Power Supply

    3. TM #3 — Regulated Power Supply Block Diagram

    4. TM #4 — Voltage-Regulating Transformers

    5. TM #5 — Diode Rectification

    6. TM #6 — Three-Phase Wye Half-Wave Rectifier

    7. TM #7 — Three-Phase Wye Full-Wave Rectifier

SUGGESTED ACTIVITIES

   8. TM #8 — Full-Wave Voltage Doubler
   9. TM #9 — Half-Wave Voltage Doubler
   10. TM #10 — Types of Voltage Regulators

E. Assignment sheets

   1. Assignment Sheet #1 — Label Power Supply Circuit Schematics
   2. Assignment Sheet #2 — Label Voltage Regulator Circuit Schematics

F. Answers to assignment sheets

G. Job sheets

   1. Job Sheet #1 — Analyze DC to DC Power Supply
   2. Job Sheet #2 — Analyze an AC to DC Half-Wave Voltage Doubler
   3. Job Sheet #3 — Analyze an AC to DC Full-Wave Voltage Doubler
   4. Job Sheet #4 — Analyze an AC to DC Selenium Rectifier Circuit
   5. Job Sheet #5 — Analyze the Operation of a Bridge Rectifier
   6. Job Sheet #6 — Construct a Silicon-Controlled Rectifier Power Circuit
   7. Job Sheet #7 — Construct a Triac Power Circuit

H. Test

I. Answers to test

III. Unit references

A. Grob, Bernard, and Milton S. Kiver. *Application of Electronics,* 2nd ed. New York: McGraw-Hill Book Company, 1966.

B. *Introduction to Power Supplies.* Barrington, Illinois: TPC Training Systems, Division of Technical Publishing Company, 1977.

C. Shrader, Robert L. *Electronic Communication,* 3rd ed. New York: McGraw-Hill Book Company, 1975.

POWER SUPPLY CIRCUITS
UNIT II

INFORMATION SHEET

I. Terms and definitions

A. Power supply — Circuit or device that provides a specific electrical output by transforming a different electrical input or converting other forms of energy

EXAMPLES: Battery, electrical generator, AC to DC converter

(NOTE: A battery converts chemical energy to electrical energy. A generator converts mechanical energy to electrical energy. An AC to DC converter transforms AC power to DC power.)

B. Inverter — Circuit or device that transforms DC power to AC power (Transparency #1)

C. Ripple — Low-amplitude variation of DC power; usually results from insufficient filtering of rectified AC

D. Regulator — Circuit or device that serves to keep voltage or current output at a constant level despite changes in output current or input voltage

E. Choke — Inductor used to filter

EXAMPLE: An inductor used in a DC power supply to restrict ripple at the output

F. Bleeder resistor — Resistor connected to large filter capacitors to drain charge when circuit power is turned off

(CAUTION: Large capacitors may store a charge sufficient enough to result in injury or death if contacted accidentally. Bleeder resistors reduce this hazard, but they may not always be present or may not be functional.)

(NOTE: Technicians should check or bleed large capacitors properly before working near them. Review the unit on capacitors for proper procedures to use when discharging large capacitors.)

G. Chopper — Circuit or device that converts DC to pulsating DC by switching it off and on (Transparency #1)

H. Battery backup — Batteries and charging circuit installed in industrial equipment to provide power when primary power source fails

I. Flux diversion — Method of controlling transformer output by a third control winding that diverts magnetic flux lines in the main windings (Transparency #6)

INFORMATION SHEET

J. Root-mean-square (rms) — Effective voltage of an AC waveform

EXAMPLE: 120 VAC rms has the same effective power as 120 VDC; its peak-to-peak voltage is about 340.

K. Shunt regulator — Controller placed in parallel to the load; bypasses excessive current and varies total current through a series resistance to control output voltage

L. Series regulator — Controller placed in line with the load; controls by varying resistance to load current

EXAMPLE: Q1 of Transparency #2

II. Abbreviations associated with power supply circuits

A. Q — Schematic designator for transistor

B. PS — Power supply

C. R_L — Load resistor

D. C — Capacitor

E. R — Resistor

F. SCR — Silicon-controlled rectifier

G. T — Terminal or schematic designator for transformer

H. XFMR — Transformer

I. CR — Diode (crystal rectifier)

J. NC — No connection; normally closed

K. DIP — Dual in-line package

L. IC — Integrated circuit

M. CT — Center tap

N. PL, DS — Pilot lamp

O. VAC — Volts alternating current

P. SUS — Silicon unilateral switch

Q. ϕ — Phase

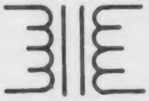
INFORMATION SHEET

III. Common power supply symbols (Figures 1-29)

A. Transformer

(NOTE: The two vertical lines between the windings indicate that the transformer has an iron core.)

FIGURE 1



B. Fuse

FIGURE 2

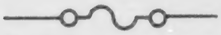
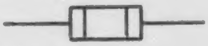
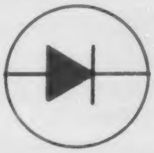


FIGURE 3



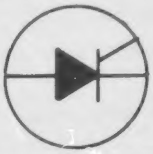
C. Diode

FIGURE 4



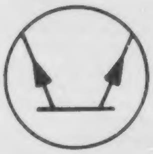
D. SCR

FIGURE 5



E. Diac

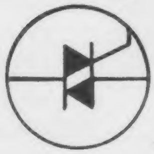
FIGURE 6



INFORMATION SHEET

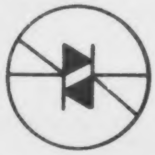
F. Triac

FIGURE 7



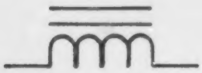
G. SUS

FIGURE 8



H. Inductor (choke)

FIGURE 9



(NOTE: Transformers or inductors shown with a line through the symbol are "saturable core" devices. This indicates that their response would become limited at higher values of operating current. The modified symbols are shown in Figures 10-11.)

EXAMPLES: Saturable cores

FIGURE 10

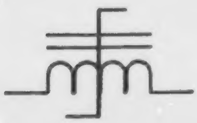
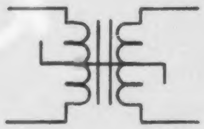
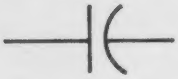


FIGURE 11



I. Capacitor

FIGURE 12

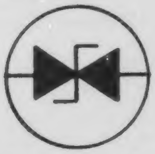


INFORMATION SHEET

J. Thyrector

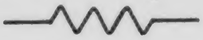
(NOTE: This type of device protects circuitry from high-voltage transients.)

FIGURE 13



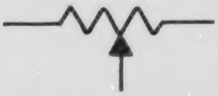
K. Resistor

FIGURE 14



L. Potentiometer

FIGURE 15



M. Lamp

(NOTE: There are several lamp symbols. The circle with the letter "R" inside denotes a red lamp. It may also be denoted by the designator "LR" for lamp, red.)

FIGURE 16

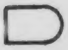
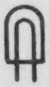


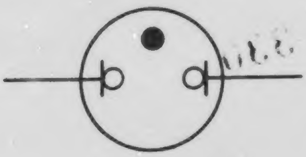
FIGURE 17

FIGURE 18



N. Neon lamp

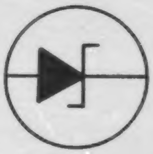
FIGURE 19



INFORMATION SHEET

O. Zener diode

FIGURE 20



P. Switch

FIGURE 21

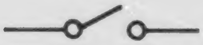
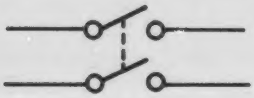
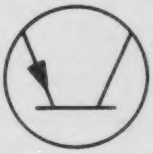


FIGURE 22



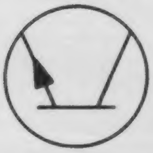
Q. pnp transistor

FIGURE 23



R. npn transistor

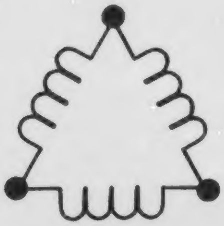
FIGURE 24



INFORMATION SHEET

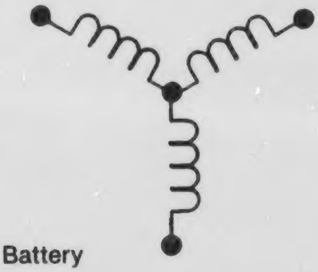
S. Three-phase delta-connected transformer

FIGURE 25



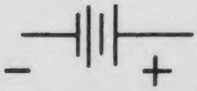
T. Three-phase wye-connected transformer

FIGURE 26



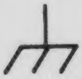
U. Battery

FIGURE 27



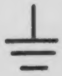
V. Chassis ground

FIGURE 28



W. Earth ground

FIGURE 29



INFORMATION SHEET

IV. Primary energy sources for power supplies

A. Electrical

EXAMPLES: 1. 120-volt AC power from a receptacle is used to provide DC voltages for an electronic instrument such as an oscilloscope.

2. A DC motor may be operated by a variable DC power supply to control revolutions per minute.

B. Mechanical

EXAMPLES: 1. The steam turbines in large power plants convert mechanical (rotational) energy into electrical energy by driving a generator.

2. Some industries may have diesel engines to drive generators in case of power failure in the utility power lines.

C. Direct energy conversion

EXAMPLES: 1. Batteries convert chemical energy into electrical energy.

2. Solar cells convert light energy into electrical energy.

(NOTE: Both batteries and generators are discussed in detail in separate units of instruction.)

V. Types of electrical power supplies and their applications

A. AC input, AC output — Used to change voltage or frequency

(NOTE: This type of power supply may be called a *converter*. The same term is used in high-frequency applications.)

EXAMPLE: A three-phase industrial motor speed controller is supplied by three-phase AC power at a variable frequency from 20 to 80 hertz.

B. AC input, DC output — Used to supply DC (Transparency #2)

(NOTE: AC to DC is the most common type of electronic power supply because AC available from utility companies must be converted to DC for use by electronic circuits.)

EXAMPLE: Industrial test instruments, computers, and electronic control circuits require DC; but industries receive only AC power from utility companies.

INFORMATION SHEET

C. DC input, DC output — Used to change voltage levels

EXAMPLE: A simple voltage-divider network is the most common DC to DC power supply; high-voltage DC required by truck-mounted oil field electronic equipment may be provided by converting the 12-volt truck power to pulsating DC, stepping the voltage up through a transformer, and finally rectifying and filtering back to DC again.

D. DC input, AC output — Used to supply AC

EXAMPLE: Very critical AC-operated equipment may be supplied in times of power failure by batteries having the output switched into pulsating DC, converted to AC through a transformer, and wave-shaped through a filter into a sine wave.

VI. Types of inverters and their uses (Transparency #1)

A. Chopper circuit — Often used with batteries for standby AC power for medium-power applications

B. Electric motor generator — Used effectively but not efficiently for high-power applications

(NOTE: Electric motor generators are seldom used in United States industry today.)

C. Oscillator — Used for small-power applications

VII. Power supply components and their applications (Transparency #2)

A. Transformer

1. Used to step AC voltages up or down
2. May be used for isolation
3. May be used to control voltage output by flux diversion
4. May have multiple taps for varying output voltage
5. Required with center-tapped output for some types of rectifier circuits

B. Diode

1. Used for rectification of AC (solid-state device)

INFORMATION SHEET

2. Used for reference voltage or regulation (Zener)

3. Used as a controllable rectifier and frequently as a switch (SCR)

4. Used to vary AC voltage levels by switching on and off (Triac)

C. Capacitor — Used to filter pulsating DC

D. Inductor — Used to filter pulsating DC

E. Transistor

1. Used as active control element to regulate voltage or current

2. Used as comparator of output and reference

VIII. Descriptions of basic power supply functions (Transparencies #2 and #3)

A. Sample — Component or elements of a power supply that measure portion of supply voltage as feedback for controlling circuitry

(NOTE: The sample is usually a voltage-divider network.)

EXAMPLES: R2, R3, and R4 of Transparency #2

B. Reference — Component or elements of a power supply that maintain constant voltage for the purpose of comparison by controlling circuitry

(NOTE: The reference element is usually a Zener diode but could be an integrated circuit.)

EXAMPLE: CR5 of Transparency #2

C. Comparator — Component or elements of a power supply that monitor voltages to detect error and produce a correction voltage for compensating circuitry

(NOTE: The comparator is usually an amplifier. It could be a single element amplifier, a differential amplifier, or an operational amplifier.)

EXAMPLE: Q3 of Transparency #2

D. Error amplifier — Circuitry or components of a power supply that boost the error-detected correction voltage to a power level sufficient to operate the compensating circuitry

EXAMPLE: Q2 of Transparency #2

E. Control circuitry — Components of a power supply that actually regulate the supply output

EXAMPLE: Q1 of Transparency #2

INFORMATION SHEET

F. Filter — Component or elements of a power supply that reduce ripple and noise

EXAMPLES: C1, C2 of Transparency #2

(NOTE: The components in the example above comprise a π filter that is quite effective.)

G. Rectifier — Circuitry or element of a power supply that transforms AC to pulsating DC

EXAMPLES: CR1, CR2, CR3, and CR4 of Transparency #2

H. Transformer — Circuitry or component of a power supply that changes the voltage level

EXAMPLE: T1 of Transparency #2

(NOTE: Transformers function as modifiers for AC, while simple resistor networks can suffice for DC voltage reduction. SCRs can modify AC voltage in conjunction with filtering.)

I. Adjust circuitry — Components of a power supply that allow for changing the output

EXAMPLE: R3 of Transparency #2

IX. Rectifier circuits (Transparencies #5-#9; Assignment Sheet #1)

A. Half-wave

(NOTE: The half-wave is simple and economical. The ripple produced is considerably worse than a full-wave because of the voids. It requires better filtering in some applications.)

B. Full-wave

C. Full-wave bridge

D. Three-phase wye half-wave

E. Three-phase wye full-wave

F. Full-wave voltage doubler

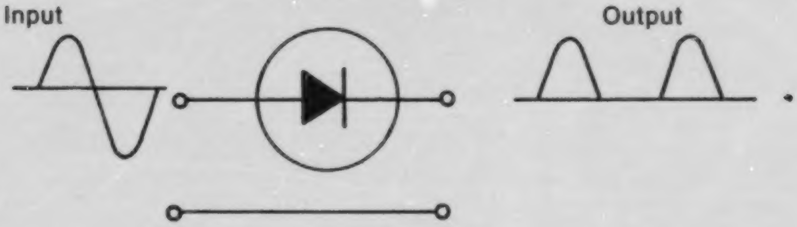
G. Half-wave voltage doubler

INFORMATION SHEET

X. Diode circuits and output waveforms (Figures 30-33)

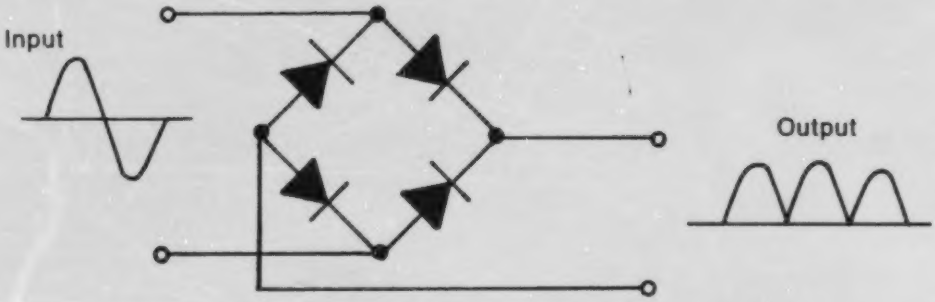
A. Half-wave

FIGURE 30


Input
Output

B. Full-wave

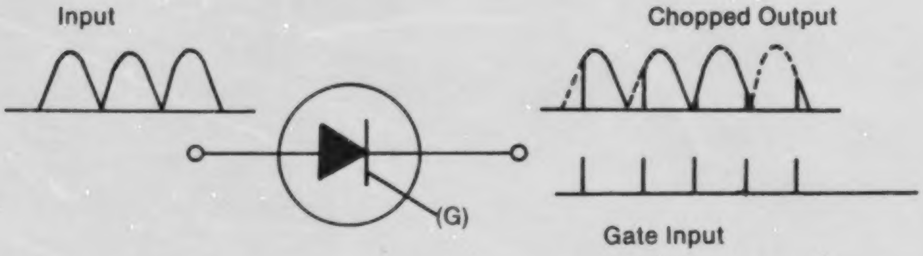
FIGURE 31


Input
Output

C. SCR

(NOTE: SCRs may be used in full-wave bridge rectifiers where they serve the dual purpose of rectifying and regulating.)

FIGURE 32

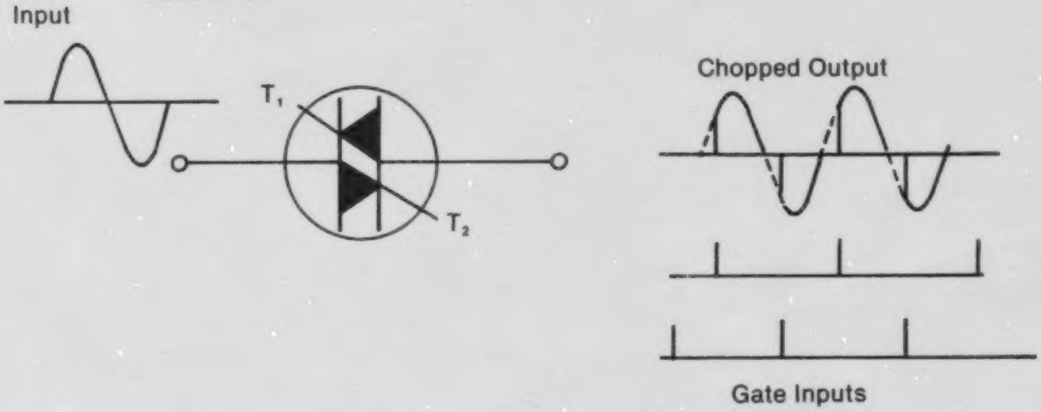

Input
Chopped Output
(G)
Gate Input

INFORMATION SHEET

D. SUS

(NOTE: SUSs may be used to regulate the AC power input to control the DC power output of a power supply. It is important to note that the power is not wasted even when a waveform is half-wave or chopped. That portion of power excluded is merely rejected as if the power switch were turned off for that instant. Thus the actual power out of a half-wave rectifier is not one-half of the power in. Except for transformer losses and diode leakage current, all of the diode circuits shown in Figures 30-33 output the same power as is input. No significant power is lost; it is merely rejected. For this reason, diode, SCR, and Triac circuits are far more efficient than rheostats for controlling power.)

FIGURE 33

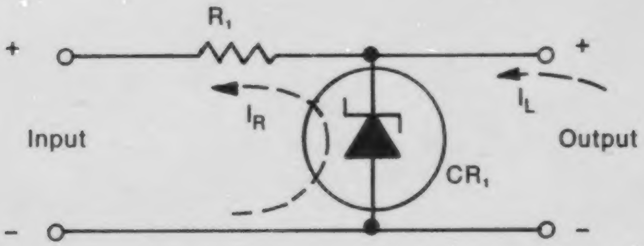


XI. Voltage regulator circuit schematics (Figures 34-38; Transparency #10; Assignment Sheet #2)

A. Zener diode shunt regulator

(NOTE: The Zener diode operates in the reverse-bias mode.)

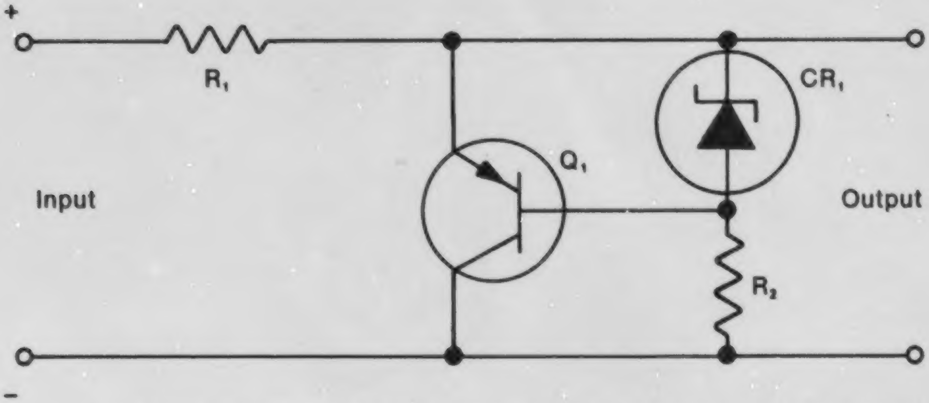
FIGURE 34



INFORMATION SHEET

B. Transistor shunt regulator

FIGURE 35



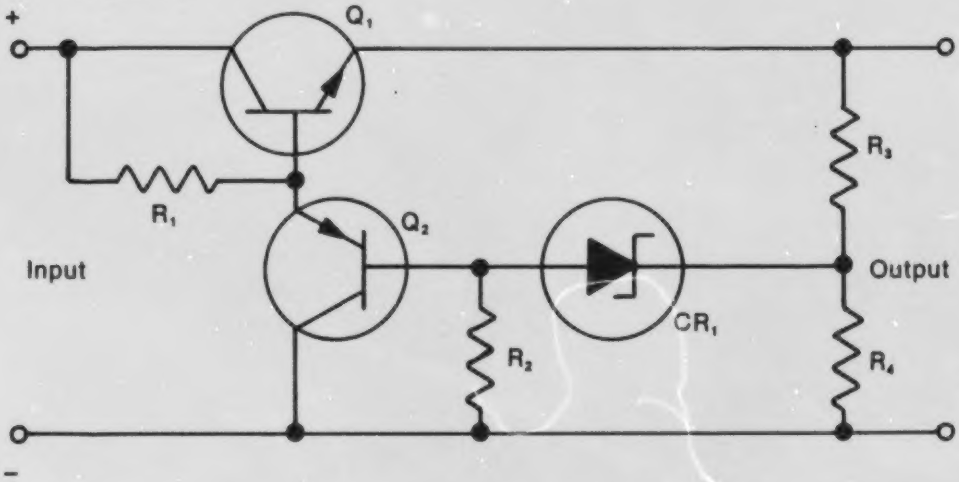
(NOTE: In this instance CR1 is acting as a voltage reference to bias Q1 base current.)

C. Transistor series regulator

EXAMPLE: Q1 of Transparency #2

(NOTE: When the voltage output decreases, the voltage drop across R4 decreases, so less current flows through CR1. Thus, less voltage is applied to the base of Q2, causing less conduction. This increases the voltage at the base of Q1 and allows more current flow through Q1, adjusting the output to the load.)

FIGURE 36

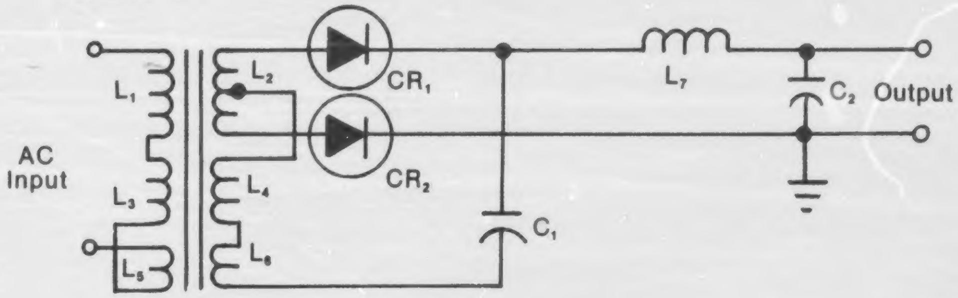


INFORMATION SHEET

D. Voltage-regulating transformer (Transparency #4)

(NOTE: When the load decreases in the rectifier circuit, windings L4 and L6 will increase in current flow, causing windings L3 and L5 to decrease in inductive reactance. This causes an increase in the primary voltage of L1, which transfers to L2 and to the load, compensating for a decrease in load resistance.)

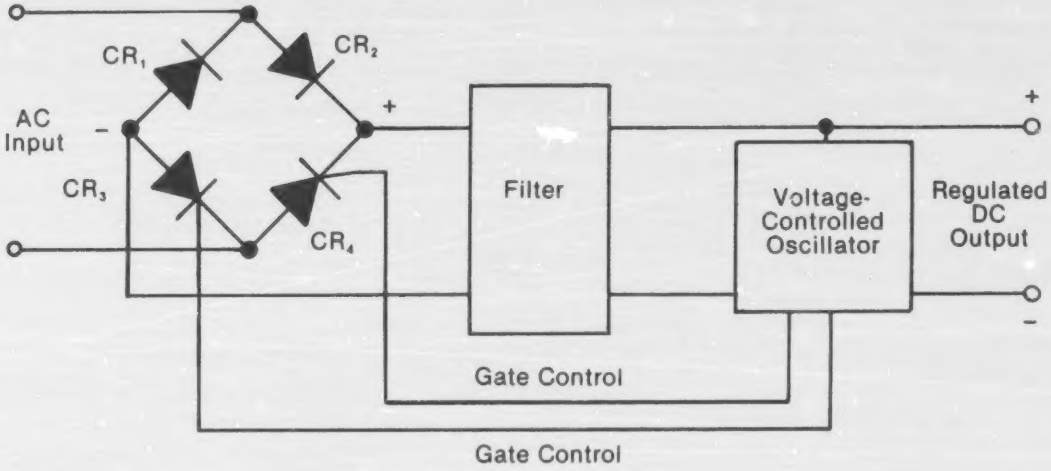
FIGURE 37


L₁
L₂
CR₁
L₇
C₂
Output
CR₂
AC Input
L₃
L₄
C₁
L₅
L₆

E. Thyristor regulator

EXAMPLES: SCR, Triac, SUS

FIGURE 38


CR₁
CR₂
+
+
AC Input
–
CR₃
Filter
Voltage-Controlled Oscillator
Regulated DC Output
CR₄
–
Gate Control
Gate Control

(NOTE: CR3 and CR4 are SCR diodes. SUS components could also have been used.)

INFORMATION SHEET

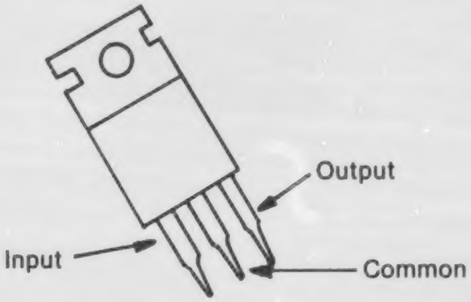
XII. Integrated circuit regulators (Figures 39 and 40)

A. Fixed regulator

(NOTE: The output is determined by the construction of the integrated circuit. The most common fixed regulator is the three-terminal regulator.)

EXAMPLE:

FIGURE 39

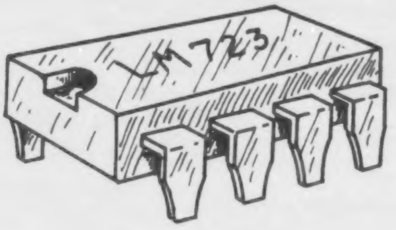


B. Programmable regulator

(NOTE: Programmable regulators allow the user to set or regulate the output. One of the most widely used is the 723. Variations of this number represent different manufacturers: LM723 is National Semiconductor, MC1723 is Motorola, and SM52723 is Texas Instruments.)

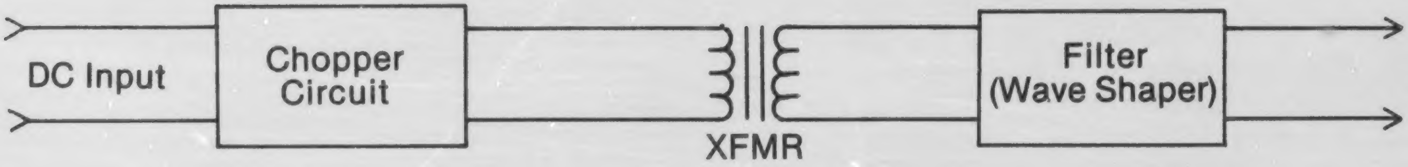
EXAMPLE:

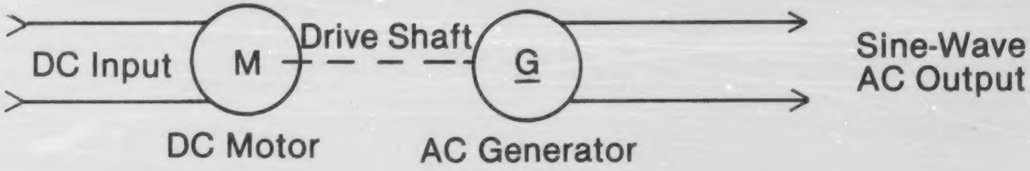
FIGURE 40

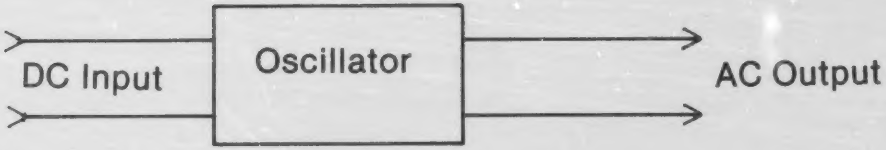


Eight-Pin Dual In-Line Package

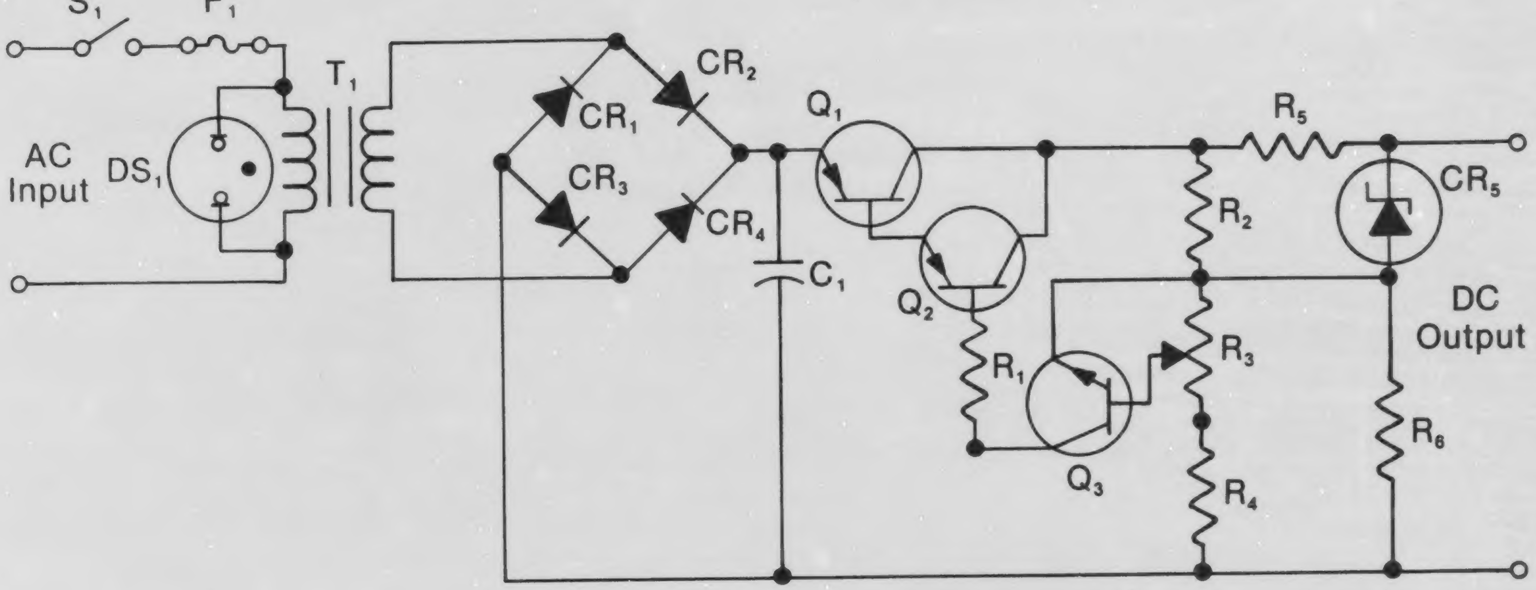
DC to AC Inverters


DC Input
Chopper Circuit
XFMR
Filter (Wave Shaper)

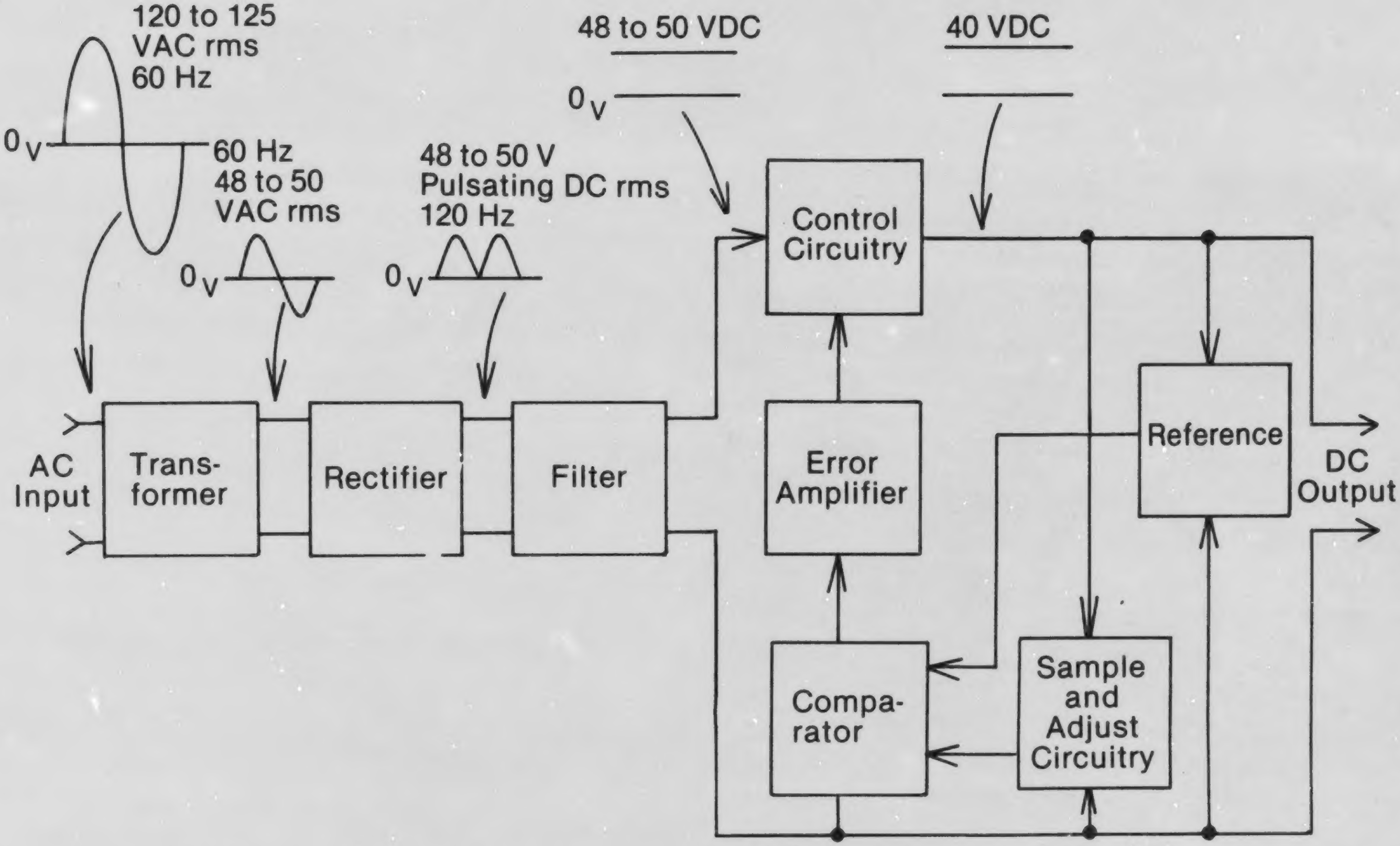

DC Input
M
Drive Shaft
G
Sine-Wave AC Output
DC Motor
AC Generator


DC Input
Oscillator
AC Output

Simple Regulated Power Supply


S1
F1
T1
AC Input
DS1
CR1
CR2
CR3
CR4
C1
Q1
Q2
Q3
R1
R2
R3
R4
R5
R6
CR5
DC Output

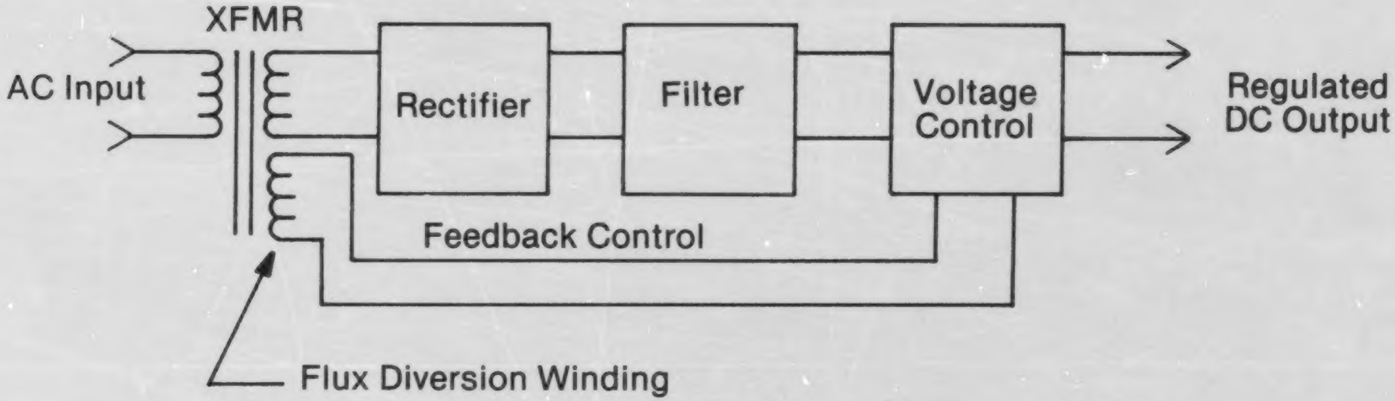
Regulated Power Supply Block Diagram


120 to 125
VAC rms
60 Hz
0V
60 Hz
48 to 50
VAC rms
0V
48 to 50 V
Pulsating DC rms
120 Hz
0V
48 to 50 VDC
0V
40 VDC
AC Input
Trans-former
Rectifier
Filter
Control Circuitry
Error Amplifier
Compa-rator
Sample and Adjust Circuitry
Reference
DC Output

TM #3

GIE - 105-B

Voltage-Regulating Transformers



XFMR

AC Input

Rectifier

Filter

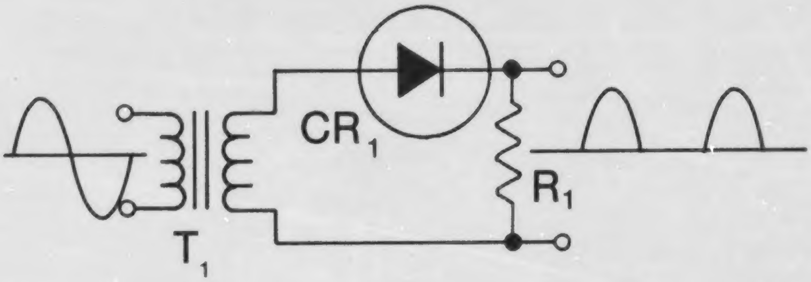
Voltage Control

Regulated DC Output

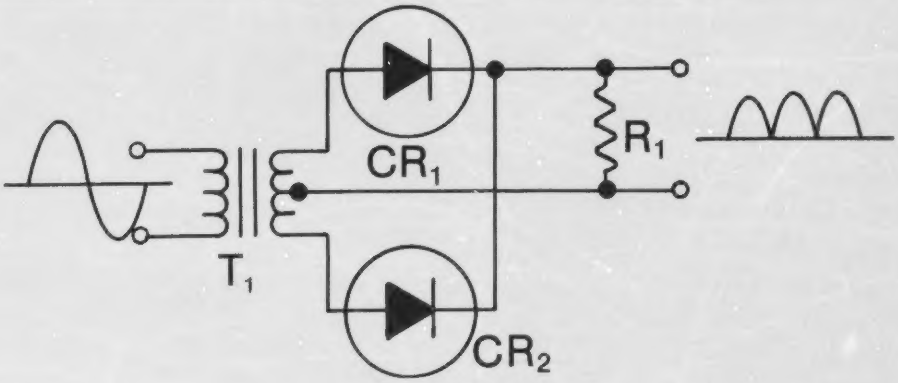
Feedback Control

Flux Diversion Winding

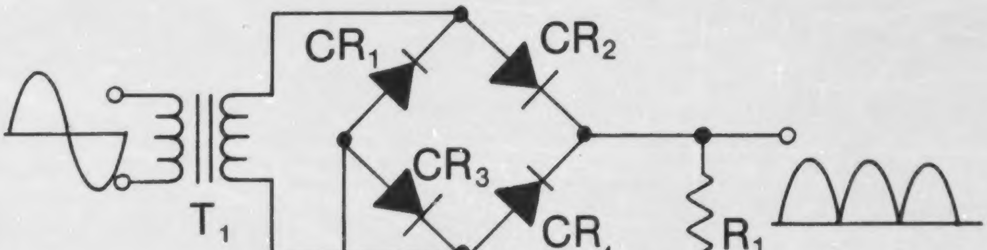
Diode Rectification



Half-Wave

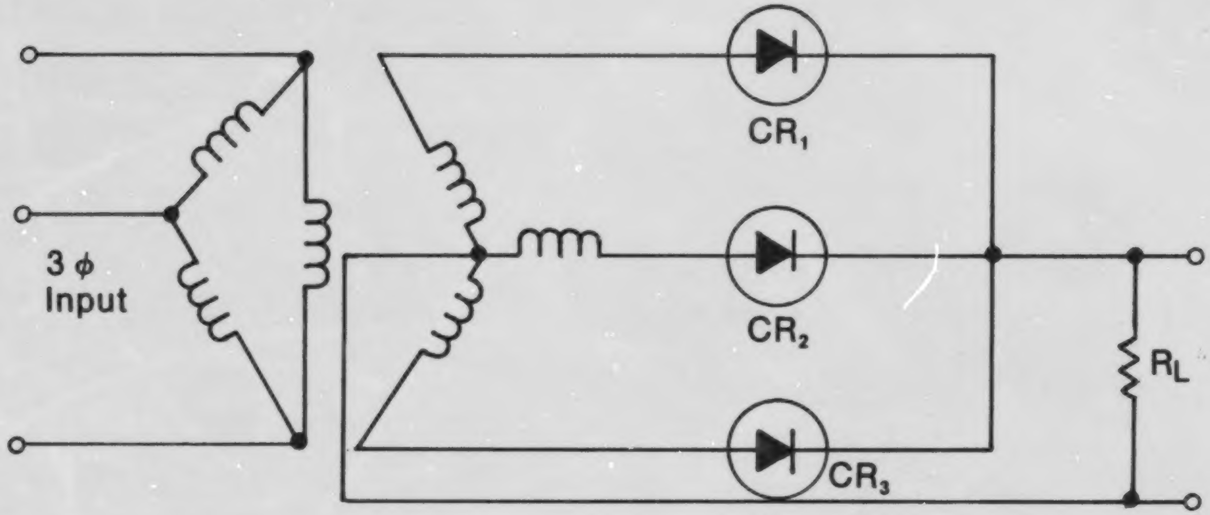

CR1
R1
T1
CR2

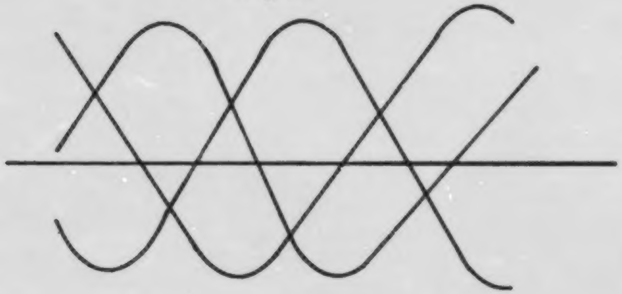
Full-Wave


CR1
CR2
CR3
CR4
T1
R1

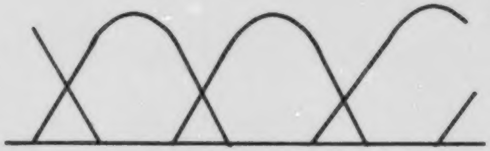
Full-Wave Bridge

Three-Phase Wye Half-Wave Rectifier


3 ϕ Input
CR$_1$
CR$_2$
CR$_3$
R$_L$



3 ϕ AC Input

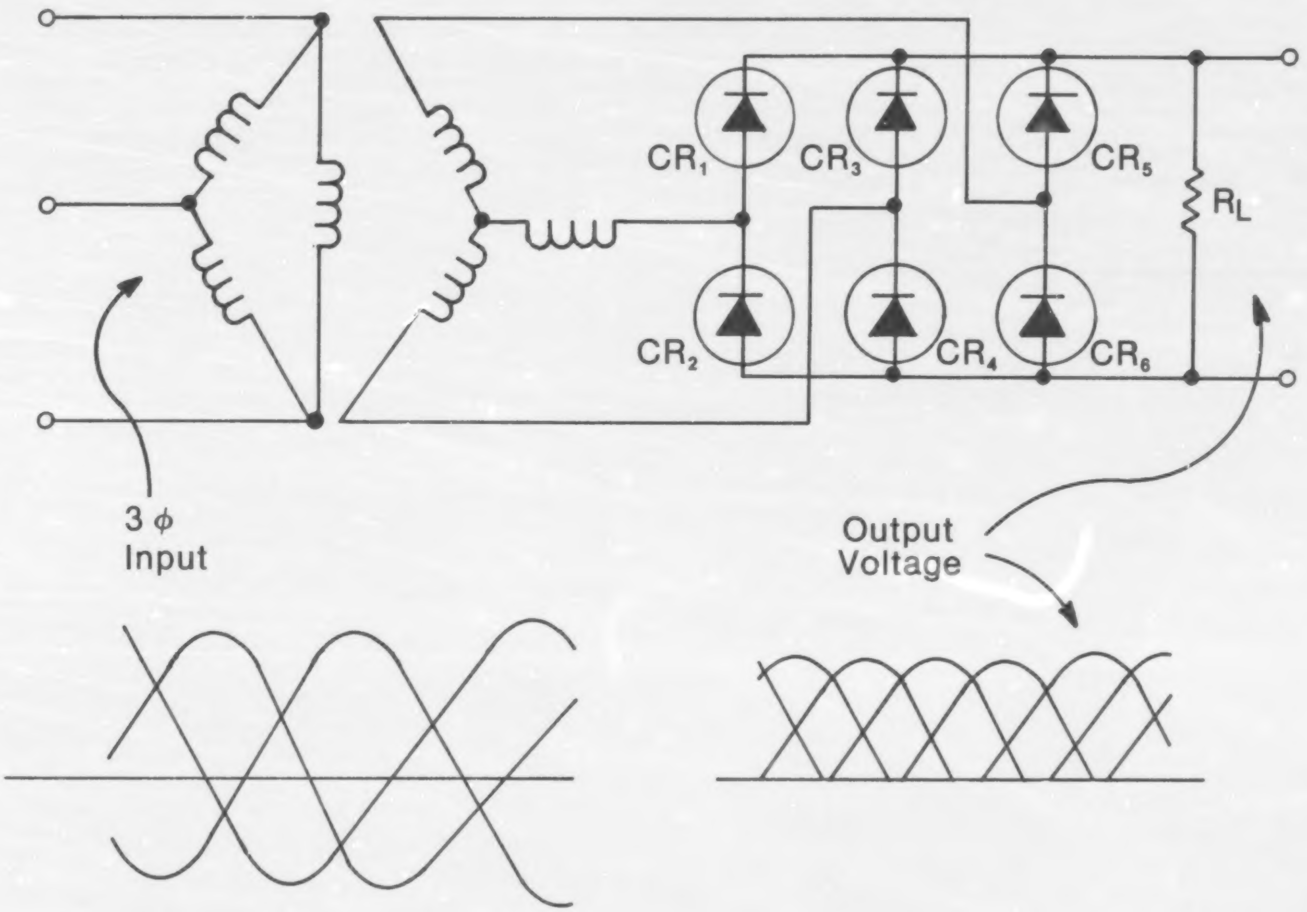


Output Voltage

TM #6

GIE - 111-B

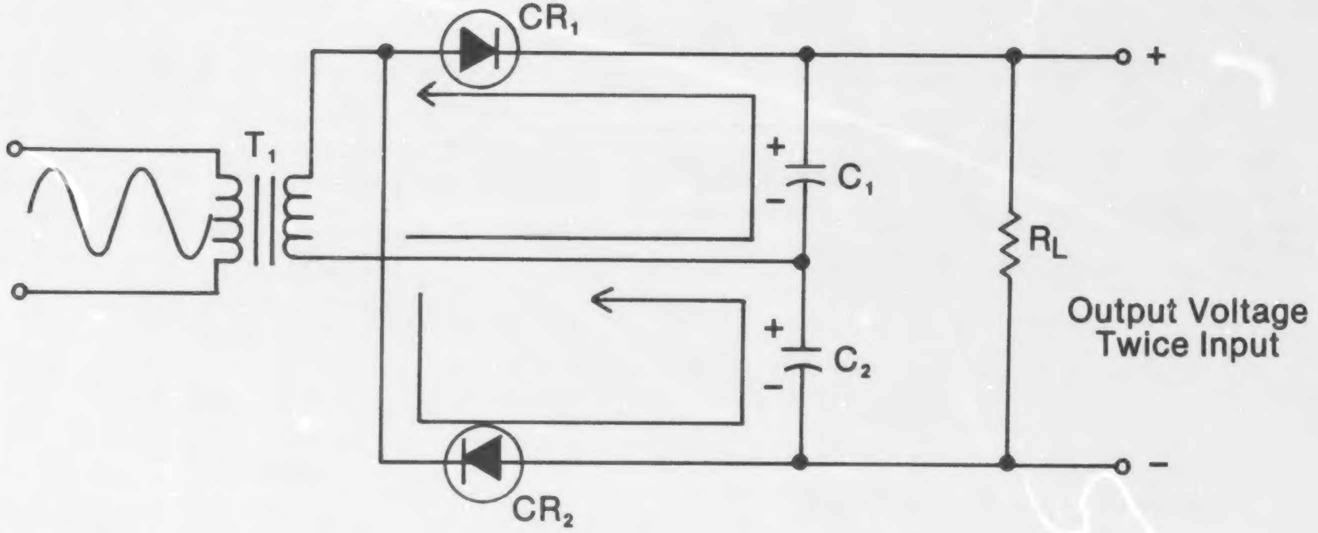
Three-Phase Wye Full-Wave Rectifier


CR$_1$
CR$_3$
CR$_5$
R$_L$
CR$_2$
CR$_4$
CR$_6$
3 ϕ
Input
Output
Voltage

TM #7

GIE - 113-B

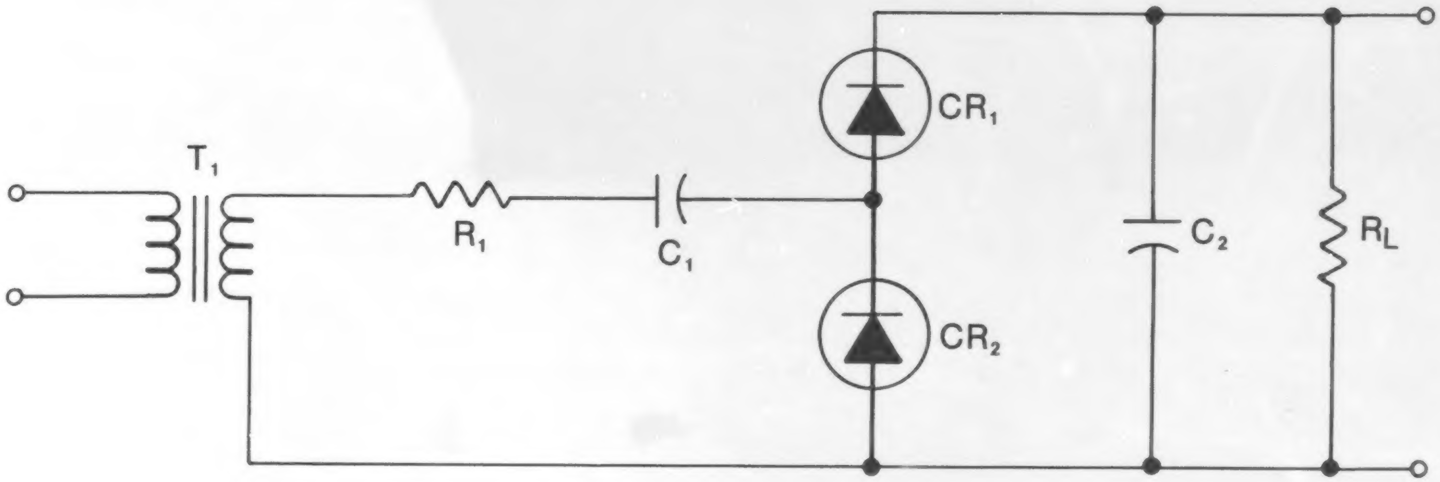
Full-Wave Voltage Doubler


CR₁
T₁
+
C₁
−
R_L
+
C₂
−
CR₂
+
−
Output Voltage
Twice Input

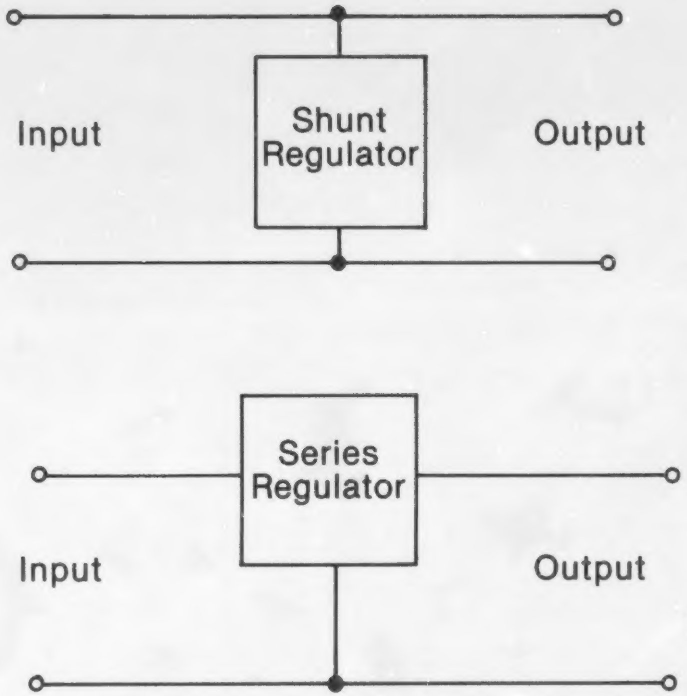
TM #8

GIE - 115-B

Half-Wave Voltage Doubler


T₁
R₁
C₁
CR₁
CR₂
C₂
R_L

Types of Voltage Regulators


Input
Shunt Regulator
Output

In Parallel with Load

Series Regulator
Input
Output

In Series with Load

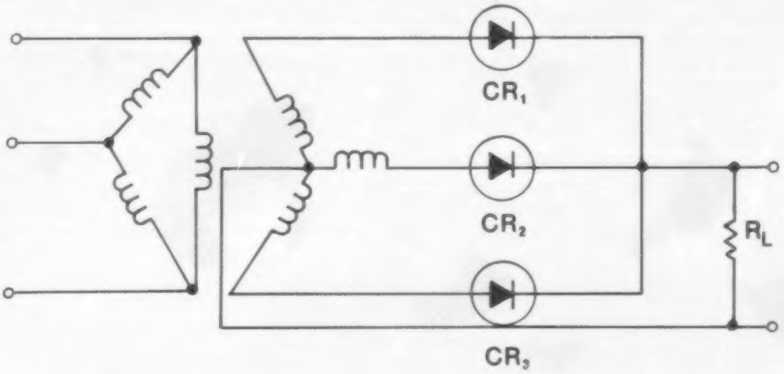
POWER SUPPLY CIRCUITS
UNIT II

ASSIGNMENT SHEET #1 — LABEL POWER SUPPLY CIRCUIT SCHEMATICS

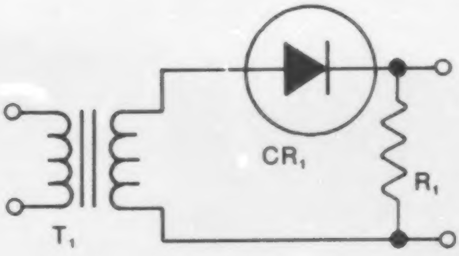
NAME ____ SCORE ________________

Power supplies have a variety of components and configurations of components representing various circuits. These schematics should be familiar to the electronics technician in order that the technician may properly use diagrams for troubleshooting procedures.

Shown below and on the following pages are various circuits used in power supplies. Label each by writing the correct names in the blanks.

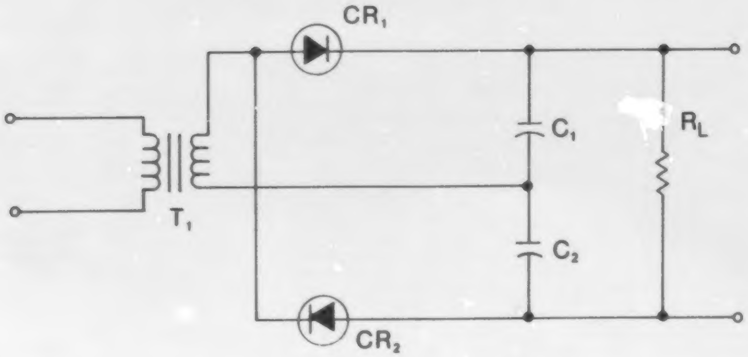


A. ____

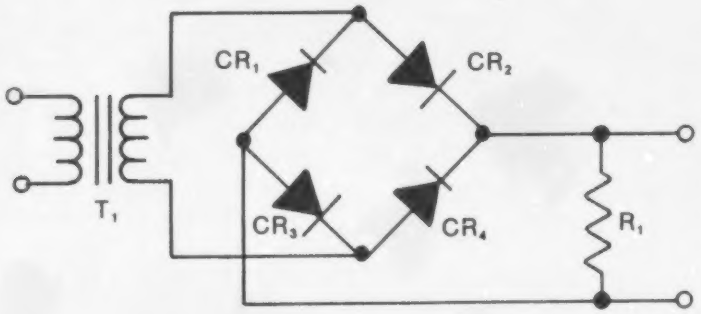


B. ____

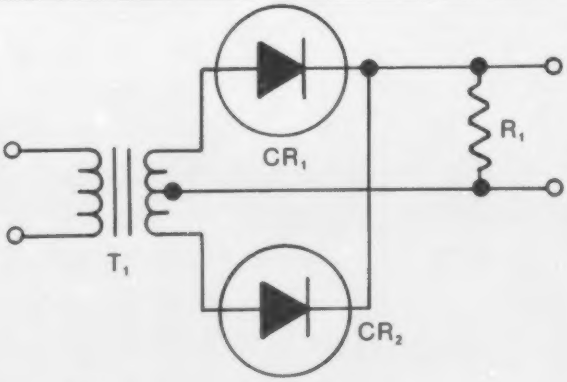
ASSIGNMENT SHEET #1


CR$_1$
C$_1$
R$_L$
T$_1$
C$_2$
CR$_2$

C. ______________________________

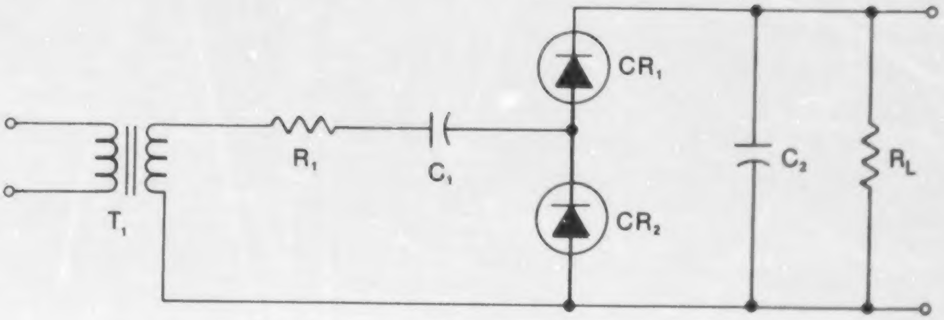

CR$_1$
CR$_2$
T$_1$
CR$_3$
CR$_4$
R$_1$

D. ______________________________


R$_1$
CR$_1$
T$_1$
CR$_2$

E. ______________________________

ASSIGNMENT SHEET #1


CR$_1$
R$_1$
C$_1$
C$_2$
R$_L$
T$_1$
CR$_2$

F. ____

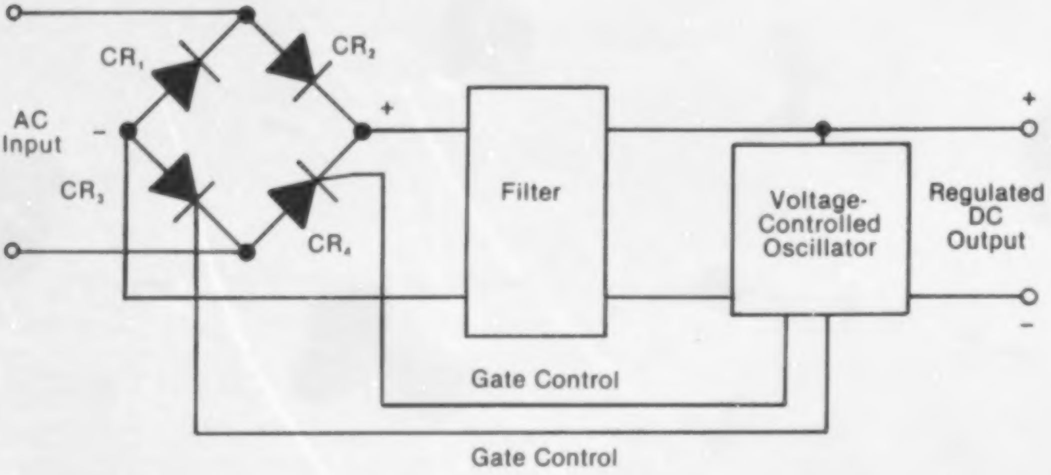
POWER SUPPLY CIRCUITS
UNIT II

ASSIGNMENT SHEET #2 — LABEL VOLTAGE REGULATOR CIRCUIT SCHEMATICS

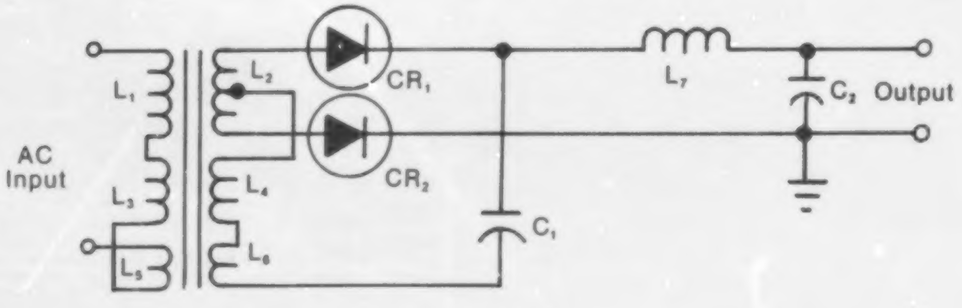
NAME ______________________________ SCORE ______________

Power supply regulators are used to regulate the output voltage in most power supplies. The electronics technician should be familiar with voltage regulator schematics in order to interpret such schematics when troubleshooting.

Shown below and on the following page are various schematics containing regulators. Label each by writing the correct names in the blanks.

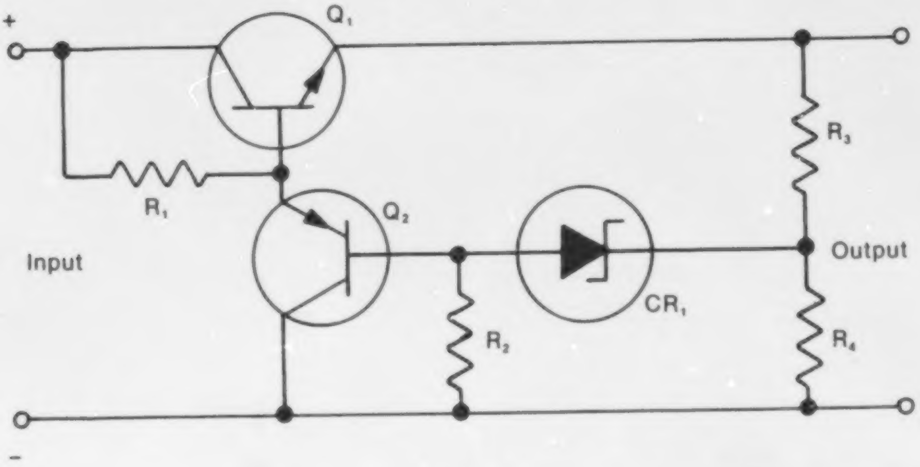

CR₁
CR₂
AC Input
−
+
CR₃
CR₄
Filter
Voltage-Controlled Oscillator
+
Regulated DC Output
−
Gate Control
Gate Control

A. ______________________________

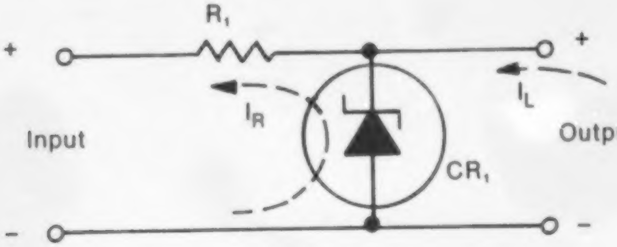

L₁
L₂
CR₁
L₇
C₂
Output
AC Input
CR₂
L₃
L₄
C₁
L₅
L₆

B. ______________________________

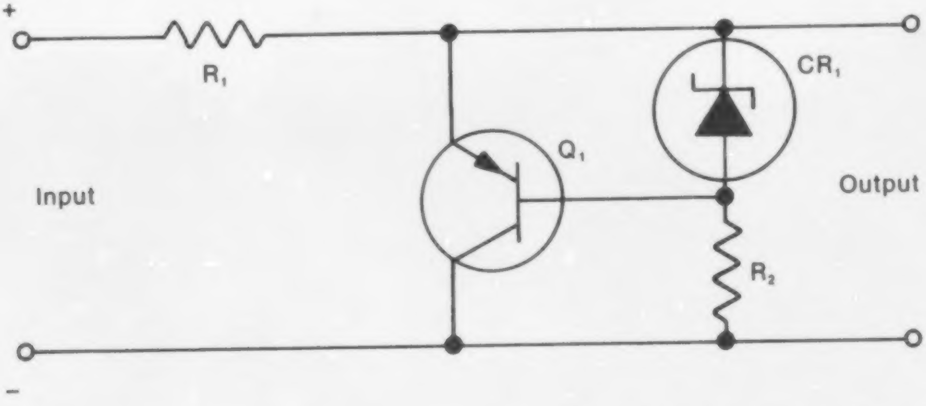
ASSIGNMENT SHEET #2


+
Q_1
R_3
R_1
Q_2
Input
Output
CR_1
R_2
R_4
–

C. ____________________


R_1
+
+
I_L
I_R
Input
Output
CR_1
–
–

D. ____________________


+
R_1
CR_1
Q_1
Input
Output
R_2
–

E. ____________________

POWER SUPPLY CIRCUITS
UNIT II

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

A. Three-phase wye half-wave rectifier

B. Half-wave rectifier

C. Full-wave voltage doubler

D. Full-wave bridge rectifier

E. Full-wave rectifier

F. Half-wave voltage doubler

Assignment Sheet #2

A. Thyristor regulator

B. Voltage-regulating transformer

C. Transistor series regulator

D. Zener diode shunt regulator

E. Transistor shunt regulator

POWER SUPPLY CIRCUITS
UNIT II

JOB SHEET #1 — ANALYZE DC TO DC POWER SUPPLY

I. Equipment and materials

  A. DC power supply

  B. Resistor, 4.7 kohm

  C. Variable resistor, 0 to 5 kohm

  D. Zener diode, IN4739 or equivalent

  E. Multimeter

  F. Various test leads

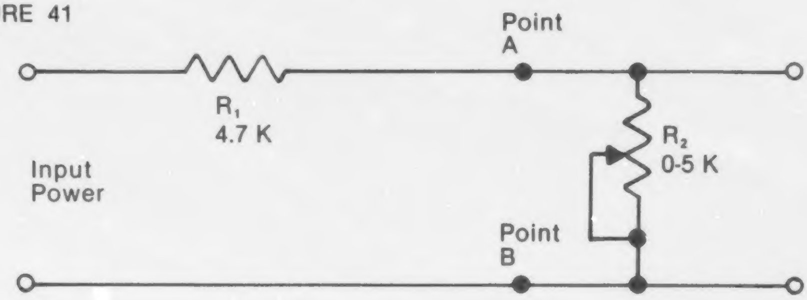
  G. Breadboard

II. Procedure

  A. Construct circuit as shown in Figure 41

  (NOTE: Have instructor check your circuit before proceeding.)

FIGURE 41



  B. Adjust power source for 25 VDC

  C. Using voltmeter, measure voltage across variable resistor while increasing resistance from minimum to maximum; record results

  Voltage = ______________________________

  ____

  D. Turn off power to circuit and add Zener diode between points A and B of circuit

  (NOTE: Connect cathode to positive, anode to negative. Have instructor check your circuit before proceeding.)

JOB SHEET #1

E. Adjust power source for 25 VDC

F. Repeat step C

   1. Record the results

      Voltage = ______________________________

      ____

      ____

   2. What difference was observed in the readings obtained in steps C and F? Why?

      ____

      ____

      ____

      (NOTE: Have the instructor check your results.)

G. Clean work area; put away materials and equipment

POWER SUPPLY CIRCUITS
UNIT II

JOB SHEET #2 — ANALYZE AN AC TO DC HALF-WAVE VOLTAGE DOUBLER

I. Equipment and materials

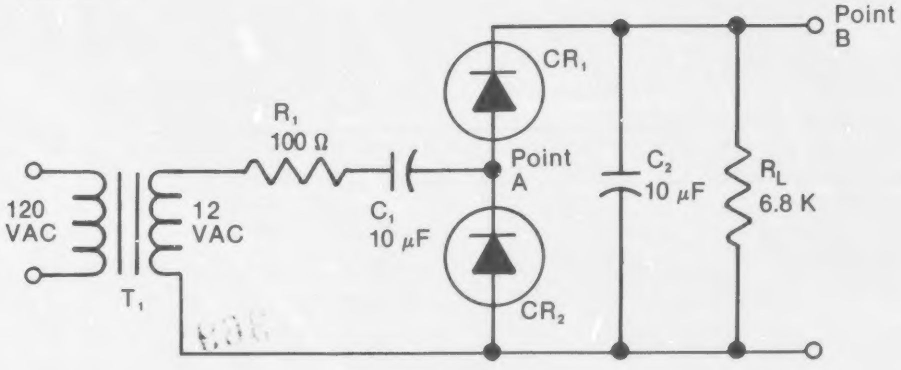
- A. Two diodes
- B. Two capacitors, each 10 microfarad
- C. Resistor, 6.8 kohm
- D. Resistor, 100 ohm
- E. Multimeter
- F. Test leads
- G. Transformer
- H. Breadboard

II. Procedure

A. Construct circuit as shown in Figure 42

(CAUTION: Do not apply power until told to do so. Follow instructions carefully. This circuit operates at 120 VAC, which can cause injury or death if contacted. Do not touch any parts of the circuit. Technicians must learn to work carefully with voltages such as this.)

FIGURE 42



B. Apply power to circuit

C. Using multimeter, measure voltage at point A to ground; record below

Voltage = ______________________________

JOB SHEET #2

D. Reconnect multimeter to point B and ground; measure voltage across load resistor and record below

   1. Voltage = ______________________

   2. What difference was observed in the readings between steps C and D? Why?

   (NOTE: Have the instructor check your results.)

E. Clean work area; put away materials and equipment

POWER SUPPLY CIRCUITS
UNIT II

JOB SHEET #3 — ANALYZE AN AC TO DC FULL-WAVE VOLTAGE DOUBLER

I. Equipment and materials

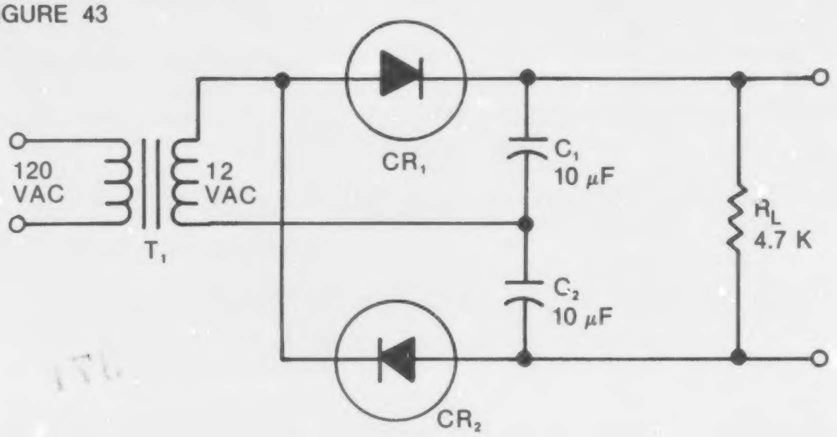
- A. Two diodes
- B. Two capacitors, each 10 microfarad
- C. Resistor, 4.7 kohm
- D. Multimeter
- E. Transformer, 120 VAC to 12 VAC
- F. Test leads
- G. Breadboard

II. Procedure

A. Construct circuit as shown in Figure 43

(CAUTION: Do not apply power until told to do so. Follow instructions carefully. This circuit operates at 120 VAC, which can cause injury or death if contacted. Do not touch any parts of the circuit. Technicians must learn to work carefully with voltages such as this.)

FIGURE 43



B. Apply power to circuit

C. Using multimeter, measure voltage across capacitor C1; record below

Voltage across C1 = ______________________________

JOB SHEET #3

D. Measure voltage across capacitor C2; record below

Voltage across C2 = ______________________________

E. Measure voltage across load resistor and record below

1. Voltage across R_L = ______________________________
2. What difference was observed in steps C, D, and E? Why?

____

____

____

(NOTE: Have instructor check your results.)

F. Clean work area; put away materials and equipment

POWER SUPPLY CIRCUITS
UNIT II

JOB SHEET #4 — ANALYZE AN AC TO DC SELENIUM RECTIFIER CIRCUIT

I. Equipment and materials

   A. Selenium rectifier diode

   B. Resistor, 4.7 kohm

   C. Test leads

   D. Diode, 1N4001 or equivalent

   E. Oscilloscope

   F. Transformer, 120 VAC to 12 VAC

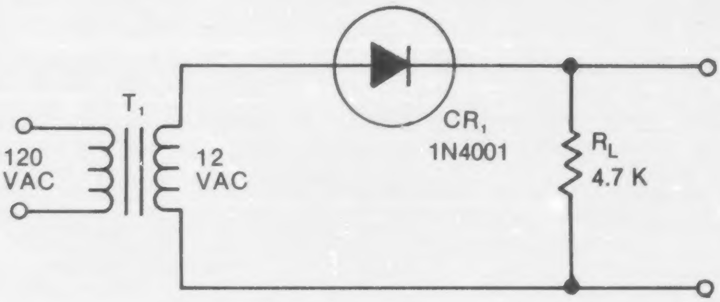
   G. Breadboard

II. Procedure

   A. Construct circuit as shown in Figure 44

   (CAUTION: Do not apply power until told to do so. Follow instructions carefully. This circuit operates at 120 VAC, which can cause injury or death if contacted. Do not touch any parts of the circuit. Technicians must learn to work carefully with voltages such as this.)

FIGURE 44



   B. Apply power to circuit

   C. Using oscilloscope, observe signal across load resistor, noting frequency and amplitude; record below

   Frequency across R_L = ______________________

   Amplitude across R_L = ______________________

JOB SHEET #4

D. Remove power from circuit

E. Replace diode with selenium rectifier; observe polarity

F. Using oscilloscope, again observe signal across load resistor and record

   1. Signal

      Frequency across R_L = ______________________________

      Amplitude across R_L = ______________________________

   2. Was there a difference between the signals in steps C and F? Why or why not?

      ____

      ____

      (NOTE: Have instructor check your results.)

G. Clean work area; put away materials and equipment

POWER SUPPLY CIRCUITS
UNIT II

JOB SHEET #5 — ANALYZE THE OPERATION OF A BRIDGE RECTIFIER

I. Equipment and materials

   A. Four diodes, 1N4001 or equivalent

   B. Resistor, 4.7 kohm

   C. Test leads

   D. Transformer, 120 VAC to 12 VAC

   E. Oscilloscope

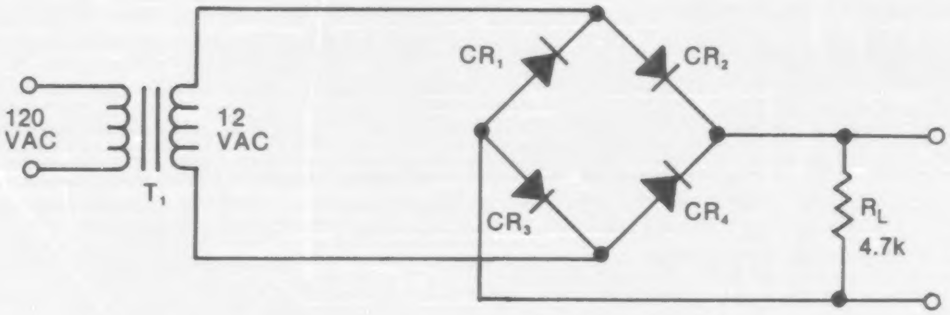
   F. Breadboard

II. Procedure

   A. Construct circuit as shown in Figure 45

   (CAUTION: Do not apply power until told to do so. Follow instructions carefully. This circuit operates at 120 VAC, which can cause injury or death if contacted. Do not touch any parts of the circuit. Technicians must learn to work carefully with voltages such as this.)

FIGURE 45



   B. Apply power to circuit

   C. Using oscilloscope, observe output signal across load resistor and record

      1. Output signal across R_L = ________________

      2. Would this circuit be considered a half-wave or full-wave rectifier circuit? Why?

      ____

JOB SHEET #5

D. Remove one diode

E. Repeat step C

  1. Output signal across R_L = ____________________

  2. Does this change the circuit as a rectifier? Why or why not?

     ____

F. Clean work area; put away materials and equipment

POWER SUPPLY CIRCUITS
UNIT II

JOB SHEET #6 — CONSTRUCT A SILICON-CONTROLLED RECTIFIER POWER CIRCUIT

I. Equipment and materials

A. Dual-trace oscilloscope with probes

B. Fuse, 1 ampere, 120 or 240 volt, with holder

C. Fuse, 5 ampere, 120 or 240 volt

D. Silicon-controlled rectifier, type 2N1846 or any 400-volt 5-ampere similar type

E. Two potentiometers, 500 ohm, 1/2 watt

F. Two diodes, 1N5625 or equivalent

G. Resistor, 2.5 kohm, 1/2 watt

H. Resistor, 1 kohm, 1/2 watt

I. Capacitor, 2 microfarad, 50 volt

J. Lamp with socket, 120 volt, 60 watt

K. Universal motor, 1/4 horsepower or less

L. Isolation transformer, 120 VAC

M. Breadboard

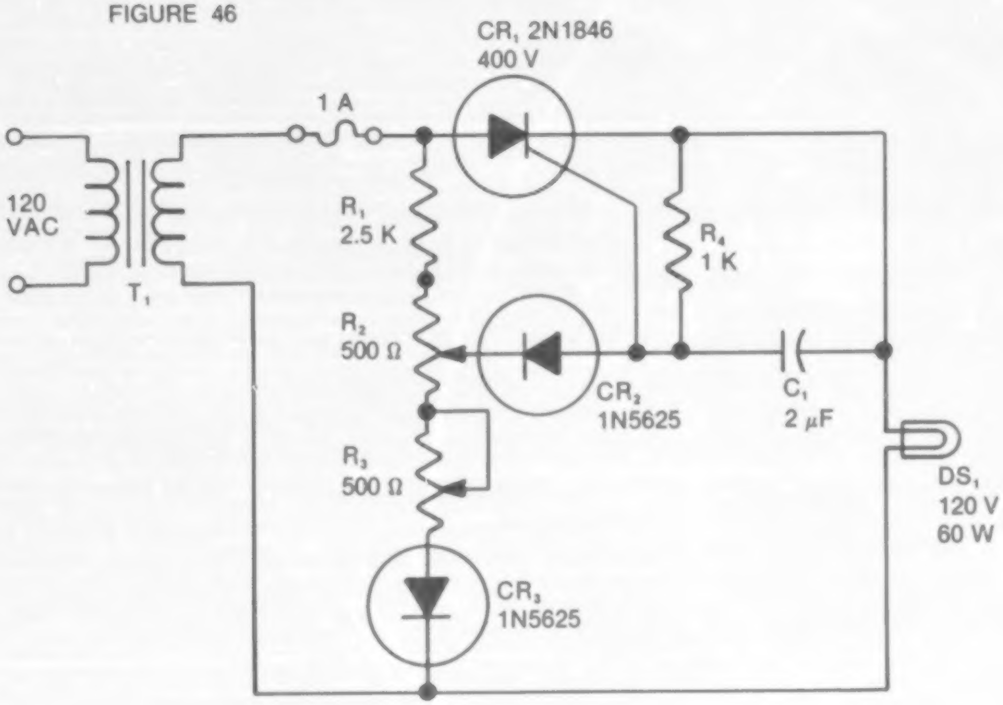
JOB SHEET #6

II. Procedure

A. Construct circuit shown in Figure 46

(CAUTION: Do not apply power until told to do so. Follow instructions carefully. This circuit operates at 120 VAC, which can cause injury or death if contacted. Do not touch any parts of the circuit. Technicians must learn to work carefully with voltages such as this.)

FIGURE 46


CR₁ 2N1846
400 V
1 A
120
VAC
T₁
R₁
2.5 K
R₂
500 Ω
R₃
500 Ω
R₄
1 K
CR₂
1N5625
C₁
2 μF
DS₁
120 V
60 W
CR₃
1N5625

B. Turn on oscilloscope; allow it to reach operating temperature and stabilize

(NOTE: Ask your instructor to inspect your circuit. If you must make changes to the circuit, have the instructor check it again before you connect the power.)

C. Adjust R2 and R3 to approximate center of their range

D. Connect circuit to 120-VAC power

(NOTE: The lamp should glow dimly.)

JOB SHEET #6

E. Use oscilloscope with probe grounded to verify that fused side of 120-VAC power is the line and that other side is neutral

F. Disconnect power; switch these leads if necessary

G. With power disconnected, attach probe ground to neutral side of circuit

H. Reconnect circuit to power

I. Connect one probe to SCR cathode; connect other probe to SCR gate

J. Adjust R2, observing oscilloscope waveforms and lamp intensity; use line triggering to get a stable display

(NOTE: Show your oscilloscope waveform display to the instructor.)

K. Disconnect power

L. Replace fuse with a 5-ampere fuse

M. Replace lamp and socket with a fractional horsepower universal motor of ¼ horsepower or less

(NOTE: Have the instructor check your circuit.)

N. Connect the circuit to power and vary R2

(NOTE: The motor speed should vary.)

O. Disconnect power

(NOTE: Discuss your results with the instructor.)

P. Clean work area; put away equipment and materials

POWER SUPPLY CIRCUITS
UNIT II

JOB SHEET #7 — CONSTRUCT A TRIAC POWER CIRCUIT

I. Equipment and materials

A. Dual-trace oscilloscope with probes

B. Fuse, 1 ampere, 120 or 240 volt with holder

C. Inductor, 100 millihenry, 1 ampere minimum

D. Three capacitors, 0.1 microfarad, 300 volt, nonpolarized

E. Potentiometer, 100 kohm, ½ watt

F. Resistor, 15 kohm, ½ watt

G. Diac, type 1N5758 or equivalent

H. Triac, RCA type SK3506, SK3612, or any 400-volt 2-ampere similar type

I. Isolation transformer, 120 VAC

J. Lamp with socket, 120 volt, 60 watt

K. Breadboard

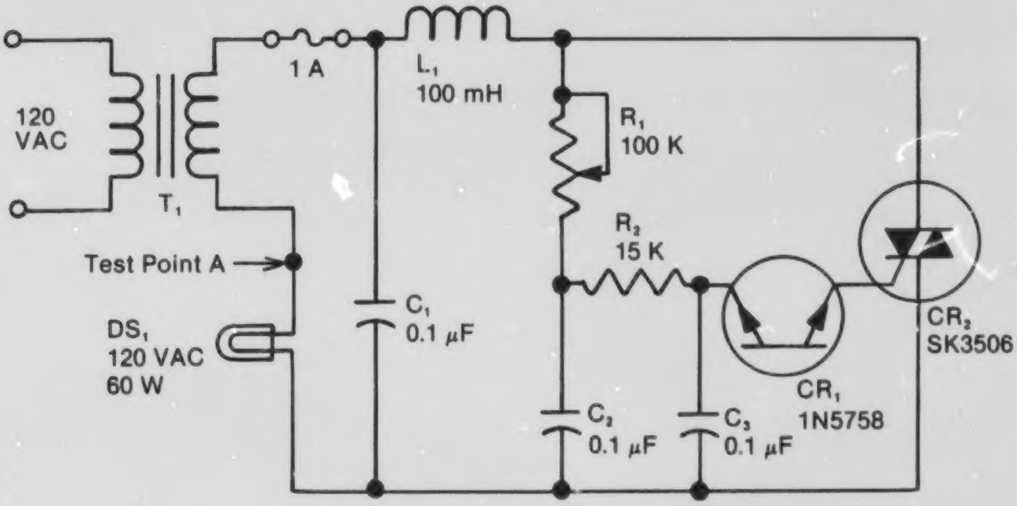
JOB SHEET #7

II. Procedure

A. Construct circuit as shown in Figure 47

(CAUTION: Do not apply power until told to do so. Follow instructions carefully. This circuit operates at 120 VAC, which can cause injury or death if contacted. Technicians must learn to work carefully with hazardous voltages. Do not touch any parts of the circuit.)

FIGURE 47


120 VAC
T₁
1 A
L₁ 100 mH
R₁ 100 K
R₂ 15 K
Test Point A
DS₁ 120 VAC 60 W
C₁ 0.1 μF
C₂ 0.1 μF
C₃ 0.1 μF
CR₁ 1N5758
CR₂ SK3506

B. Set R1 to approximate center of its range

C. Apply power to circuit

(NOTE: The lamp should glow dimly.)

D. Use oscilloscope to verify that fused lead of input is the line and other lead is neutral

E. Connect one oscilloscope channel to Triac gate; connect other channel to Triac and lamp junction line

JOB SHEET #7

F. Connect one probe ground to test point A

G. Adjust oscilloscope for a stable dual-trace display, varying R1 while monitoring oscilloscope and lamp intensity

(NOTE: Show your display waveforms to and discuss your results with the instructor.)

H. Clean work area; put away equipment and materials

POWER SUPPLY CIRCUITS
UNIT II

TEST

NAME ______________________________ SCORE ______________

1. Match terms associated with power supplies to their correct definitions. Write the correct numbers in the blanks. Definitions are continued on the following page.

______a. Circuit or device that transforms DC power to AC power

______b. Circuit or device that provides a specific electrical output by transforming a different electrical input or converting other forms of energy

______c. Low-amplitude variation of DC power; usually results from insufficient filtering of rectified AC

______d. Controller placed in parallel to the load; bypasses excessive current and varies total current through a series resistance to control output voltage

______e. Resistor connected to large filter capacitors to drain charge when circuit power is turned off

______f. Circuit or device that converts DC to pulsating DC by switching it off and on

______g. Effective voltage of an AC waveform

______h. Inductor used to filter

______i. Controller placed in line with the load; controls by varying resistance to load current

______j. Method of controlling transformer output by a third control winding that diverts magnetic flux lines in the main windings

1. Chopper
2. Ripple
3. Battery backup
4. Power supply
5. Bleeder resistor
6. Regulator
7. Shunt regulator
8. Inverter
9. Series regulator
10. Choke
11. Flux diversion
12. Root-mean-square (rms)

TEST

______k. Circuit or device that serves to keep voltage or current output at a constant level despite changes in output current or input voltage

______l. Batteries and charging circuit installed in industrial equipment to provide power when primary power source fails

2. Interpret abbreviations associated with power supply circuits. Write the correct names in the blanks.

a. DIP — ______________________________

b. PL,DS — ______________________________

c. IC — ______________________________

d. Q — ______________________________

e. XMFR — ______________________________

f. SUS — ______________________________

g. CT — ______________________________

h. NC — ______________________________

i. R_L — ______________________________

j. C — ______________________________

k. SCR — ______________________________

l. CR — ______________________________

m. T — ______________________________

n. VAC — ______________________________

o. ϕ — ______________________________

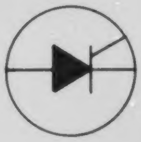
p. PS — ______________________________

q. R — ______________________________

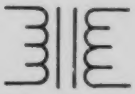
TEST

3. Identify common power supply symbols. Write the correct names in the blanks.

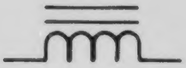
Transformer
Fuse
Diode
SCR
Diac
Switch
Three-phase, delta-connected transformer
SUS
Chassis ground
Triac
Inductor (choke)
Capacitor
Lamp
pnp transistor
Three-phase, wye-connected transformer
Thyrector
Resistor
Potentiometer
Neon lamp
Zener diode
npn transistor
Battery
Earth ground



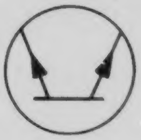
a. ______________________________



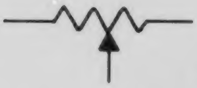
b. ______________________________



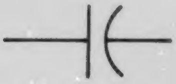
c. ______________________________



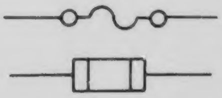
d. ______________________________



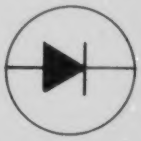
e. ______________________________



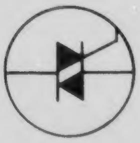
f. ______________________________



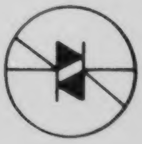
g. ______________________________



h. ______________________________

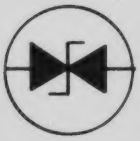


i. ______________________________

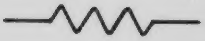


j. ______________________________

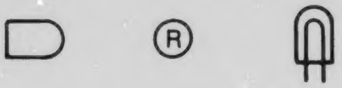
TEST



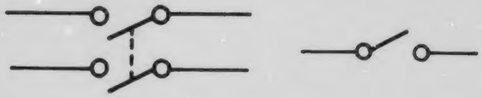
k. ______________________________



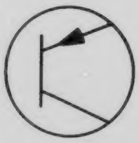
l. ______________________________



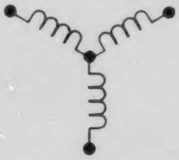
m. ______________________________



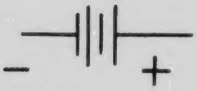
n. ______________________________



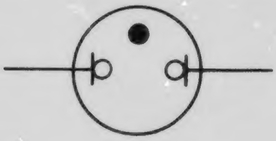
o. ______________________________



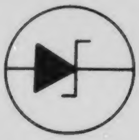
p. ______________________________



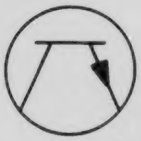
q. ______________________________



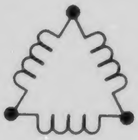
r. ______________________________



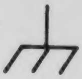
s. ______________________________



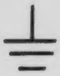
t. ______________________________



u. ______________________________



v. ______________________________



w. ______________________________

TEST

4. Name the primary energy sources for power supplies.

a. ____________________

b. ____________________

c. ____________________

5. Match types of electrical power supplies to their correct applications. Write the correct numbers in the blanks.

______a. Used to supply DC

______b. Used to change voltage levels

______c. Used to change voltage or frequency

______d. Used to supply AC

1. AC input, AC output
2. AC input, DC output
3. DC input, DC output
4. DC input, AC output

6. Match types of inverters to their correct uses. Write the correct numbers in the blanks.

______a. Used effectively but not efficiently for high-power applications

______b. Used for small-power applications

______c. Often used with batteries for standby AC power for medium-power applications

1. Chopper circuit
2. Electric motor generator
3. Oscillator

7. Match power supply components to their correct applications. Write the correct numbers in the blanks. Answers may be used more than once. Some blanks may contain more than one answer. Applications are continued on the following page.

______a. Used to step AC voltages up or down

______b. Used for reference voltage or regulation (Zener)

______c. Used as comparator of output and reference

______d. May be used for isolation

______e. Used to filter pulsating DC

______f. Used to vary AC voltage levels by switching on and off (Triac)

______g. Used as active control element to regulate voltage or current

______h. Required with center-tapped output for some types of rectifier circuits

______i. May be used to control voltage output by flux diversion

1. Diode
2. Capacitor
3. Transformer
4. Transistor
5. Inductor

TEST

______j. May have multiple taps for varying output voltage

______k. Used for rectification of AC (solid-state device)

______l. Used as a controllable rectifier and frequently as a switch (SCR)

8. Match basic power supply functions to their correct descriptions. Write the correct numbers in the blanks.

______a. Component or elements of a power supply that monitor voltages to detect error and produce a correction voltage for compensating circuitry

______b. Component or elements of a power supply that reduce ripple and noise

______c. Components of a power supply that allow for changing the output

______d. Circuitry or element of a power supply that transforms AC to pulsating DC

______e. Component or elements of a power supply that measure portion of supply voltage as feedback for controlling circuitry

______f. Circuitry or component of a power supply that changes the voltage level

______g. Components of a power supply that actually regulate the supply output

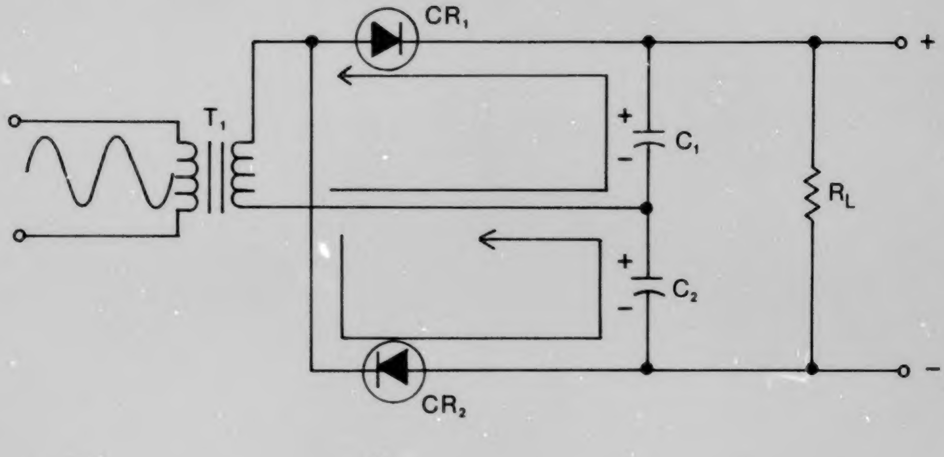
______h. Component or elements of a power supply that maintain constant voltage for the purpose of comparison by controlling circuitry

______i. Circuitry or components of a power supply that boost the error-detected correction voltage to a power level sufficient to operate the compensating circuitry

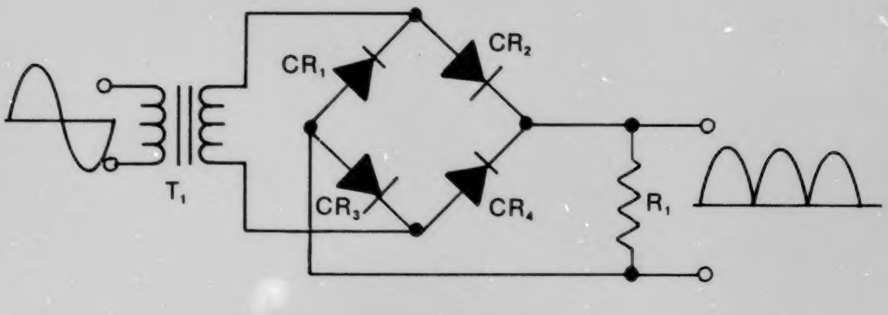
1. Sample
2. Reference
3. Comparator
4. Error amplifier
5. Control circuitry
6. Filter
7. Rectifier
8. Transformer
9. Adjust circuitry

TEST

9. Label various rectifier circuits. Write the correct names in the blanks.

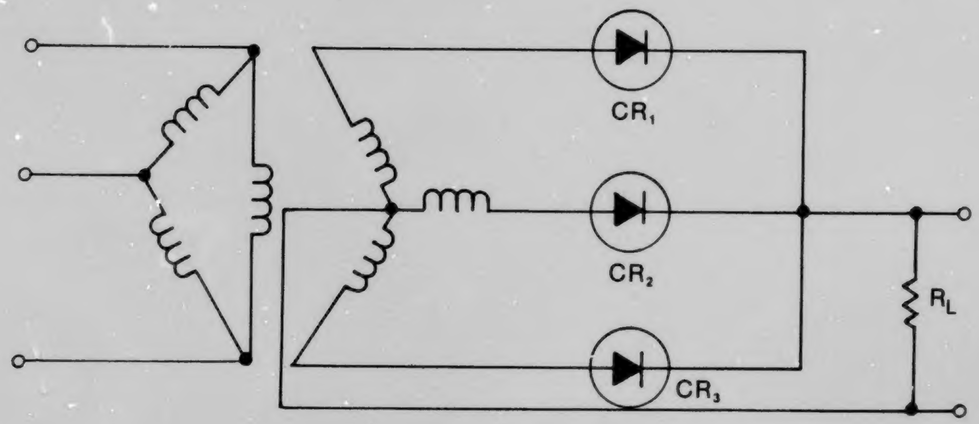

CR$_1$
T$_1$
+
C$_1$
−
R$_L$
+
C$_2$
−
CR$_2$
+
−

a. ______________________________

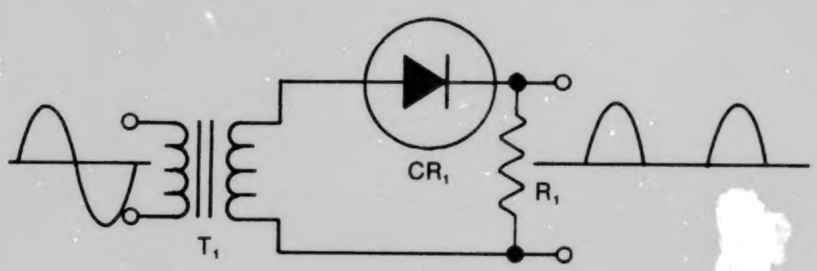

CR$_1$
CR$_2$
T$_1$
CR$_3$
CR$_4$
R$_1$

b. ______________________________

TEST

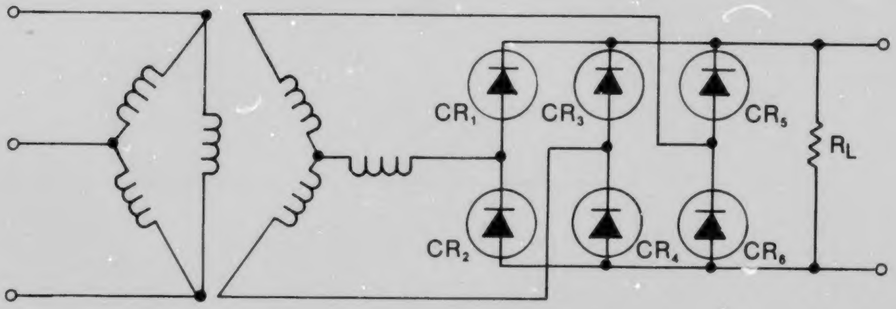

CR$_1$
CR$_2$
CR$_3$
R$_L$

c. ______________________________

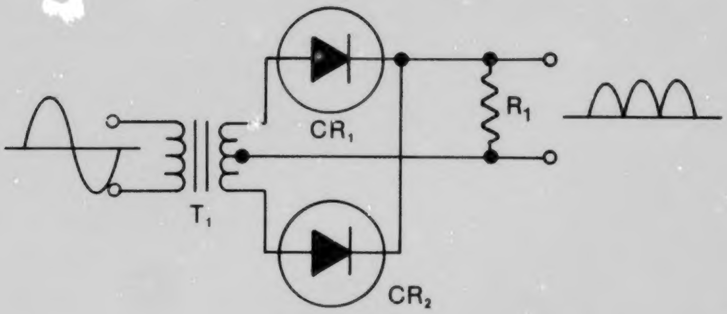


d. ______________________________

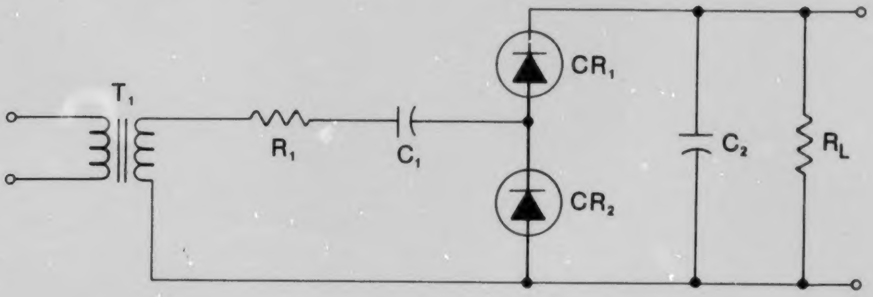
TEST


CR₁
CR₂
CR₃
CR₄
CR₅
CR₆
R_L

e. ______________________________


CR₁
CR₂
R₁
T₁

f. ______________________________

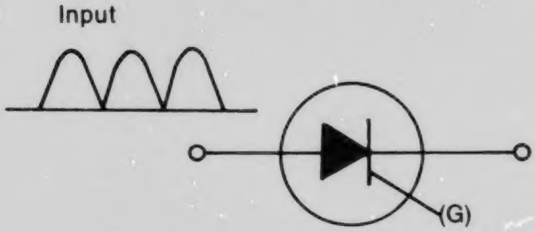

T₁
R₁
C₁
CR₁
CR₂
C₂
R_L

g. ______________________________

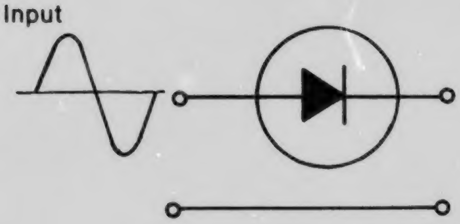
TEST

10. Match diode output waveforms to their correct diode circuits. Write the correct numbers in the blanks on the left. Circuits are continued on the next page.

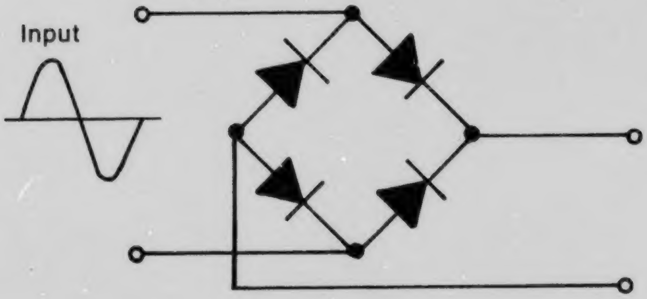
_____a. SCR



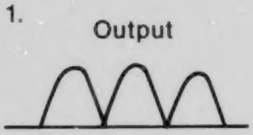
_____b. Half-wave



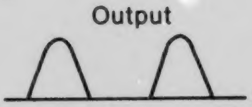
_____c. Full-wave



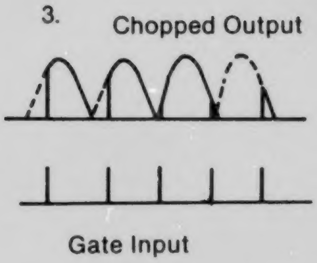
1.



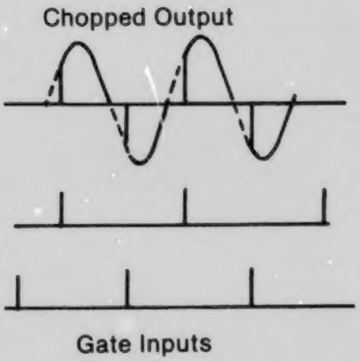
2.



3.

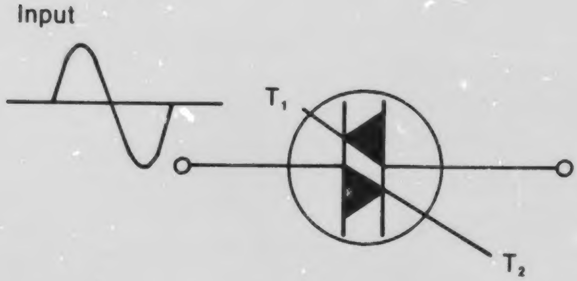

Chopped Output
Gate Input

4.

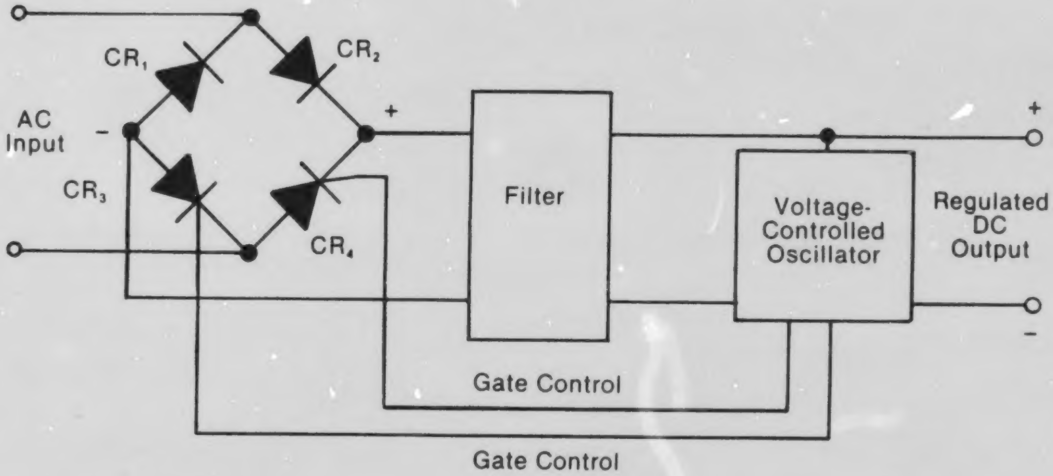

Chopped Output
Gate Inputs

TEST

_____d. SUS

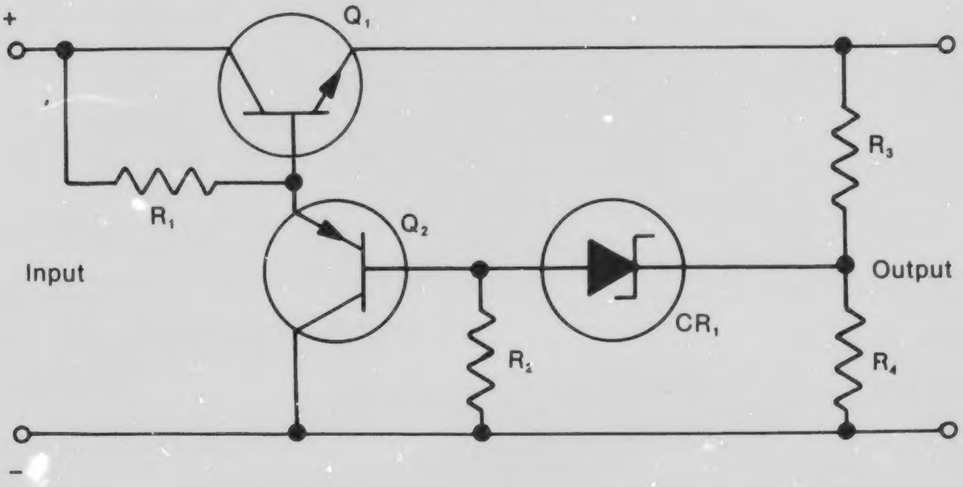


11. Label voltage regulator circuit schematics. Write the correct names in the blanks.

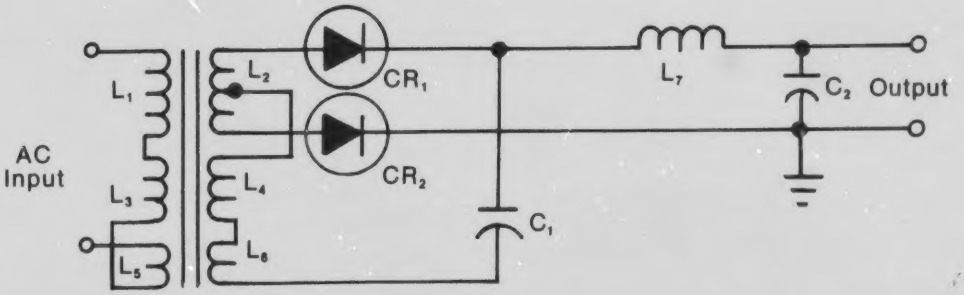

CR₁
CR₂
CR₃
CR₄
AC Input
-
+
Filter
Voltage-Controlled Oscillator
Regulated DC Output
+
-
Gate Control
Gate Control

a. ______________________________

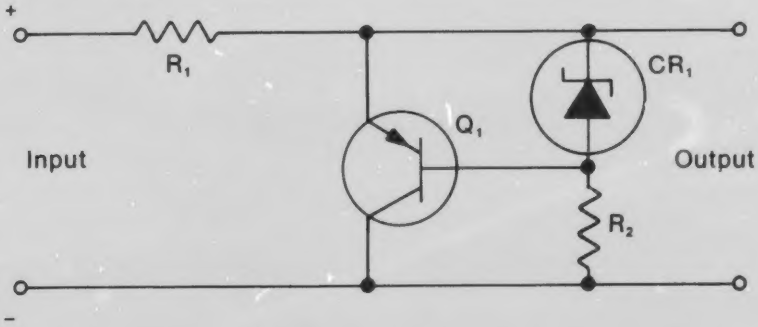
TEST


+
Q₁
R₁
Q₂
Input
CR₁
R₂
R₃
Output
R₄
–

b. ____

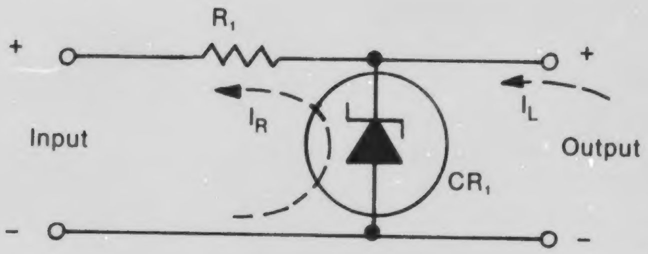

L₁
L₂
CR₁
L₇
C₂
Output
AC Input
CR₂
L₃
L₄
C₁
L₅
L₆

c. ____


+
R₁
CR₁
Q₁
Input
Output
R₂
–

d. ____

TEST



e. ____

12. Name integrated circuit regulators.

a. ____

b. ____

(NOTE: Test questions 13 and 14 list the assignment and job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

13. Label power supply circuit schematics.

14. Demonstrate the ability to

  a. Analyze DC to DC power supply.

  b. Analyze an AC to DC half-wave voltage doubler.

  c. Analyze an AC to DC full-wave voltage doubler.

  d. Analyze an AC to DC selenium rectifier circuit.

  e. Analyze the operation of a bridge rectifier.

  f. Construct a silicon-controlled rectifier power circuit.

  g. Construct a Triac power circuit.

POWER SUPPLY CIRCUITS
UNIT II

ANSWERS TO TEST

1.

a.	8	g.	12
b.	4	h.	10
c.	2	i.	9
d.	7	j.	11
e.	5	k.	6
f.	1	l.	3

2. a. Dual in-line package
   b. Pilot lamp
   c. Integrated circuit
   d. Schematic designator for transistor
   e. Transformer
   f. Silicon unilateral switch
   g. Center tap
   h. No connection; normally closed
   i. Load resistor
   j. Capacitor
   k. Silicon-controlled rectifier
   l. Diode (crystal rectifier)
   m. Terminal or schematic designator for transformer
   n. Volts alternating current
   o. Phase
   p. Power supply
   q. Resistor

ANSWERS TO TEST

3.
   a. SCR
   b. Transformer
   c. Inductor (choke)
   d. Diac
   e. Potentiometer
   f. Capacitor
   g. Fuse
   h. Diode
   i. Triac
   j. SUS
   k. Thyrector
   l. Resistor
   m. Lamp
   n. Switch
   o. pnp transistor
   p. Three-phase wye-connected transformer
   q. Battery
   r. Neon lamp
   s. Zener diode
   t. npn transistor
   u. Three-phase delta-connected transformer
   v. Chassis ground
   w. Earth ground

ANSWERS TO TEST

4.
- a. Electrical
- b. Mechanical
- c. Direct energy conversion

5.

a.	2	c.	1
b.	3	d.	4

6.

a.	2
b.	3
c.	1

7.

a.	3	d.	3	g.	4	j.	3
b.	1	e.	2, 5	h.	3	k.	1
c.	4	f.	1	i.	3	l.	1

8.

a.	3	f.	8
b.	6	g.	5
c.	9	h.	2
d.	7	i.	4
e.	1		

ANSWERS TO TEST

9. a. Full-wave voltage doubler
   b. Full-wave bridge
   c. Three-phase wye half-wave
   d. Half-wave
   e. Three-phase wye full-wave
   f. Full-wave
   g. Half-wave voltage doubler

10. a. 3 c. 1
    b. 2 d. 4

11. a. Thyristor regulator
    b. Transistor series regulator
    c. Voltage-regulating transformer
    d. Transistor shunt regulator
    e. Zener diode shunt regulator

12. a. Fixed regulator
    b. Programmable regulator

13. Evaluated to the satisfaction of the instructor

14. Performance skills evaluated to the satisfaction of the instructor

FILTERING CIRCUITS
UNIT III

UNIT OBJECTIVE

After completing this unit, the student should be able to construct and analyze filter circuits. The student will show this knowledge by completing assignment sheets, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with filtering circuits to their correct definitions.
2. Match abbreviations associated with filtering circuits to their correct interpretations.
3. Match symbols associated with filtering circuits to their correct interpretations.
4. State the primary applications of filters.
5. Label prefixes with their correct powers of ten.
6. Match frequency bands to their correct ranges.
7. Match filter circuit components to their correct functions.
8. Describe filters classified according to their functions.
9. Label filter configurations.
10. Distinguish among component oppositions to power transfer.
11. Calculate reactance.
12. Calculate impedance.
13. Calculate resonant frequency.
14. Calculate percentage of ripple for a filter circuit.
15. Calculate component values in a filter circuit.
16. List sources of electrical noise.
17. Determine filter effects on various frequency bands.

OBJECTIVE SHEET

18. Demonstrate the ability to

    a. Analyze various LC filters.

    b. Analyze capacitive filter circuits.

    c. Analyze LC filter circuits.

    d. Analyze a band-pass filter.

FILTERING CIRCUITS
UNIT III

SUGGESTED ACTIVITIES

I. Suggested activities

  A. Make transparencies.

  B. Provide students with objective sheet.

  C. Discuss unit and specific objectives.

  D. Provide students with information, assignment, and job sheets.

  E. Discuss information and assignment sheets.

  F. Demonstrate the effect of filters on rectified DC.

  G. Demonstrate the effect of filters on various AC voltages, using an oscilloscope and signal generator.

  H. Show students how filters may be used for making square waves into sinusoidal ones, or for creating integrators and differentiators.

  I. Point out to students how filters such as the π, L, and T resemble those letters.

  J. Give test.

  K. Critique test.

  L. Reteach if necessary.

II. Instructional materials

  A. Objective sheet

  B. Suggested activities

  C. Information sheet

  D. Transparency masters

    1. TM #1 — AC and DC Waveforms

    2. TM #2 — Impedance Formulas

    3. TM #3 — Impedance Formulas (continued)

SUGGESTED ACTIVITIES

4. TM #4 — Power Supply Ripple
5. TM #5 — Bandwidth and Quality
6. TM #6 — Low-Pass Filters
7. TM #7 — High-Pass Filters
8. TM #8 — Band-Pass Filters
9. TM #9 — Band-Reject Filters
10. TM #10 — Radio Frequency Applications

E. Assignment Sheets

1. Assignment Sheet #1 — Calculate Component Values for Filter Circuits
2. Assignment Sheet #2 — Determine Filter Effects of Various Frequency Bands

F. Answers to assignment sheets

G. Job sheets

1. Job Sheet #1 — Analyze Various LC Filters
2. Job Sheet #2 — Analyze Capacitive Filter Circuits
3. Job Sheet #3 — Analyze LC Filter Circuits
4. Job Sheet #4 — Analyze a Band-Pass Filter

H. Test

I. Answers to test

III. Unit references

A. *Industrial Electronics Training Program: Filters, Lesson III.* Barrington, Illinois: TPC Training Systems, Division of Technical Publishing Company, 1978.

B. Temes, Lloyd. *Electronic Circuits for Technicians,* 2nd ed. New York: McGraw-Hill Book Company, 1977.

C. Zbar, Paul B., and Joseph G. Sloop. *Electricity-Electronics Fundamentals,* 2nd ed. New York: McGraw-Hill Book Company, 1977.

FILTERING CIRCUITS
UNIT III

INFORMATION SHEET

I. Terms and definitions

   A. Filter — Circuit that reacts to alternating electromagnetic waveforms and reduces or separates certain frequencies

   B. Ripple — Undesirable low-frequency pulsating component of DC power

   C. Radio frequency integrity — Ability of a circuit or electronic device to withstand external interference radio waves

   D. Radio waves — High-frequency transmitted electromagnetic waves generated by transmitters, lightning, and electrical equipment

   E. Hertz — Unit of frequency equal to one cycle per second

   F. Active filter — Filter circuit containing active components such as diodes and transistors

   G. Passive filter — Filter circuit containing only passive components such as resistors, capacitors, and inductors

   H. Reactive components — Components that change impedance characteristics in response to frequency changes

      EXAMPLES: Capacitors, inductors, reactors, coils, chokes

   I. Noise — High-frequency interference

   J. Band — Range of frequencies

   K. Harmonic — Integer multiple of a frequency

      EXAMPLE: A crystal oscillating at 1 kilohertz may excite a tank circuit tuned to its second harmonic, 2 kilohertz, or its third harmonic, 3 kilohertz, and so on.

   L. Resonant frequency — Frequency at which a circuit's reactive components are equal

   M. Reactance — Opposition to AC resulting from capacitance or inductance

      (NOTE: An inductor has reactance and resistance. DC current would not be subject to impedance, but AC current would be subject to both resistance and reactance.)

INFORMATION SHEET

N. Impedance — Combined effects to AC of resistance, capacitive reactance, and inductive reactance

O. Frequency response — Measure of a circuit's or instrument's effectiveness in transmitting different frequencies applied to it

II. Abbreviations associated with filtering circuits

A. RFI — Radio frequency interference; radio frequency integrity

B. FCC — Federal Communications Commission

C. FAA — Federal Aviation Administration

D. Q — Quality (of a filter or component)

E. Bw — Bandwidth

F. Hz — Hertz

G. Fl — Filter

H. F — Farad

I. pF — Picofarad

J. H — Henry

K. CMR — Common-mode rejection

L. emi — Electromagnetic interference

(NOTE: Electromagnetic interference is similar to radio frequency interference but also includes low frequencies and electromagnetics.)

M. Freq, f — Frequency

N. LC — Inductive/capacitive circuit

O. RC — Resistive/capacitive circuit

P. X_C — Capacitive reactance

Q. X_L — Inductive reactance

R. Z — Impedance

S. R — Resistance

INFORMATION SHEET

T. C — Capacitance

U. L — Inductance

V. f_r — Resonant frequency

W. CH — Channel

X. f_c — Frequency cutoff or cutoff frequency

Y. MF or μF — Microfarads

(NOTE: Capacitors are not feasible in the millifarad and certainly not in the megafarad ranges. Due to typesetting and stamping, the capital letter "M" is used for micro, and is understood as such when referring to a capacitor.)

Z. E_{DC} — Direct current voltage

AA. E_{ave} — Average voltage

BB. rms — Root mean square

CC. pk-pk — Peak to peak

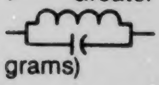
DD. VDC — Steady direct current

III. Symbols associated with filtering circuits

A. π — Greek letter pi, mathematical constant equal to approximately 3.1416

B. < — Less than

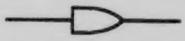
C. > — Greater than

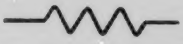
D.  — Wave trap (as shown on power transmission one-line diagrams)

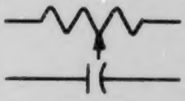
(NOTE: A wave trap is a band-reject filter used in power transmission lines to block high-frequency signals used for signalling automatic substation disconnects.)

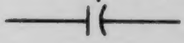
E. √ — Square root

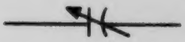
F. ∞ — Infinite (extremely large)

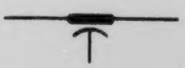
G.  — Probe

H.  — Fixed resistor

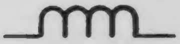
I.  — Variable resistor (potentiometer)

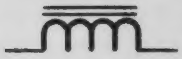
J.  — Capacitor

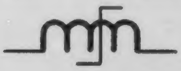
K.  — Variable capacitor (trimmer)

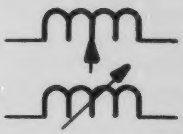
L.  — Feedthrough capacitor

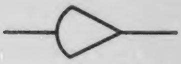
INFORMATION SHEET

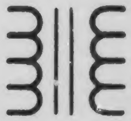
M.  — Air core inductor (choke)

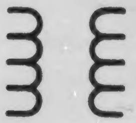
N.  — Iron core inductor

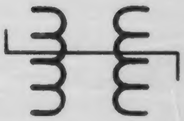
O.  — Saturable core inductor

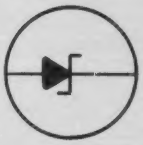
P.  — Variable core inductor (tuning slug)

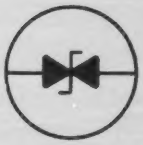
Q.  — Operational amplifier

R.  — Iron core transformer

S.  — Air core transformer

T.  — Saturable core transformer

U.  — Zener diode

V.  — Thyrector

INFORMATION SHEET

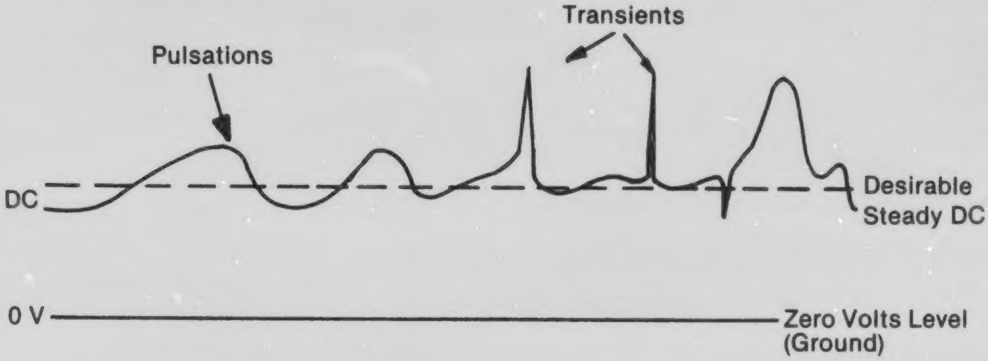
IV. Primary applications of filters (Figures 1-3; Transparency #1)

A. Removing pulsations and transients from DC

(NOTE: Often steady DC is required for component operation and protection. Filters help to eliminate pulsations and transients.)

EXAMPLE:

FIGURE 1

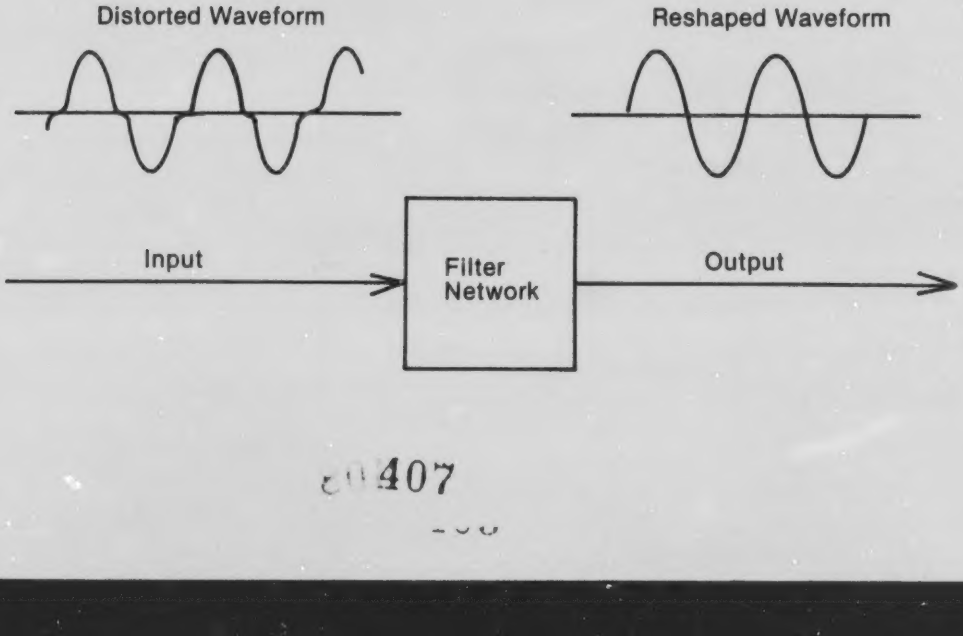

Transients
Pulsations
DC
Desirable Steady DC
0 V
Zero Volts Level (Ground)

B. Shaping waveforms

(NOTE: The distortion shown in Figure 2 is common when thyristors are used in high-power application. The AC supply to other equipment can become distorted.)

EXAMPLE:

FIGURE 2

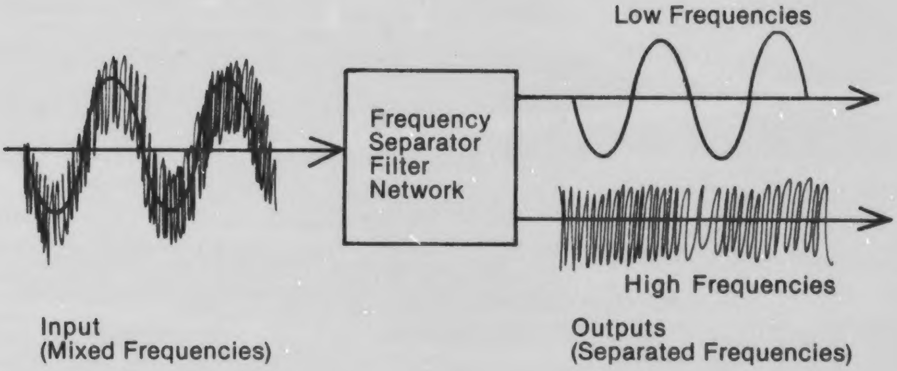

Distorted Waveform
Reshaped Waveform
Input
Filter Network
Output

INFORMATION SHEET

C. Separating frequencies

EXAMPLE:

FIGURE 3


Low Frequencies
Frequency Separator Filter Network
High Frequencies
Input (Mixed Frequencies)
Outputs (Separated Frequencies)

V. Prefixes and their powers of ten

(NOTE: There are more multiplier symbols in the metric system, but those listed below represent the most common ones in electronics.)

A. p (pico) — 10^{-12}

B. n (nano) — 10^{-9}

C. μ (micro) — 10^{-6}

D. m (milli) — 10^{-3}

E. k (kilo) — 10^{3}

F. M (mega) — 10^{6}

G. G (giga) — 10^{9}

H. T (tera) — 10^{12}

VI. Frequency bands and their ranges (Transparency #10)

A. VLF (very low frequency) — Below 30 kHz

B. LF (low frequency) — 30 kHz to 300 kHz

(NOTE: As yet undefined is the band ELF [extremely low frequency], in the range of a few hundred hertz or less. This range is being used by the U.S. Navy for communications with submarines; and 60 Hz AC, of course, would be in this range.)

INFORMATION SHEET

C. MF (medium frequency) — 300 kHz to 3 MHz

D. HF (high frequency) — 3 MHz to 30 MHz

E. VHF (very high frequency) — 30 MHz to 300 MHz

F. UHF (ultra-high frequency) — 300 MHz to 3 GHz

G. SHF (super high frequency) — 3 GHz to 30 GHz

H. EHF (extremely high frequency) — 30 GHz to 300 GHz

VII. Functions of filter circuit components

A. Resistor — Passes all frequencies with the same impedance

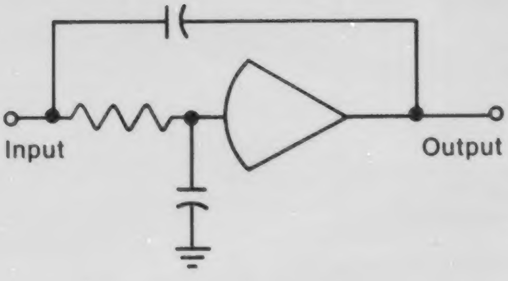
B. Capacitor — Passes high frequencies with less impedance than low frequencies

C. Inductor (choke) — Passes low frequencies with less impedance than high frequencies

D. Operational amplifier — Utilizes feedback to perform low-frequency filtering without inductors (Figures 4 and 5)

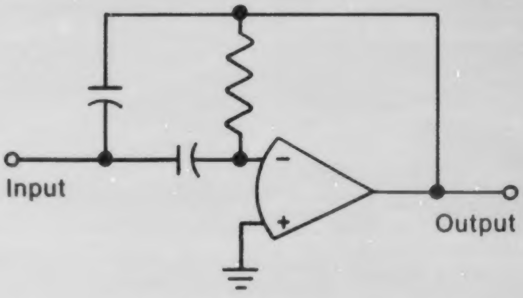
EXAMPLES:

FIGURE 4



Low-Pass Network

FIGURE 5



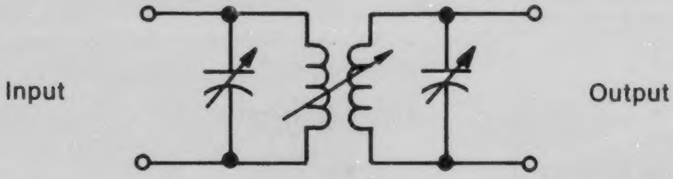
Band-Pass Network

INFORMATION SHEET

E. Transformer — Often used to isolate and filter, usually in conjunction with capacitors (Figure 6)

EXAMPLE:

FIGURE 6



Tuned-Input, Tuned-Output
Transformer Coupling
(Narrow Band-Pass)

F. Zener diode — Used to filter high-voltage transients of one polarity

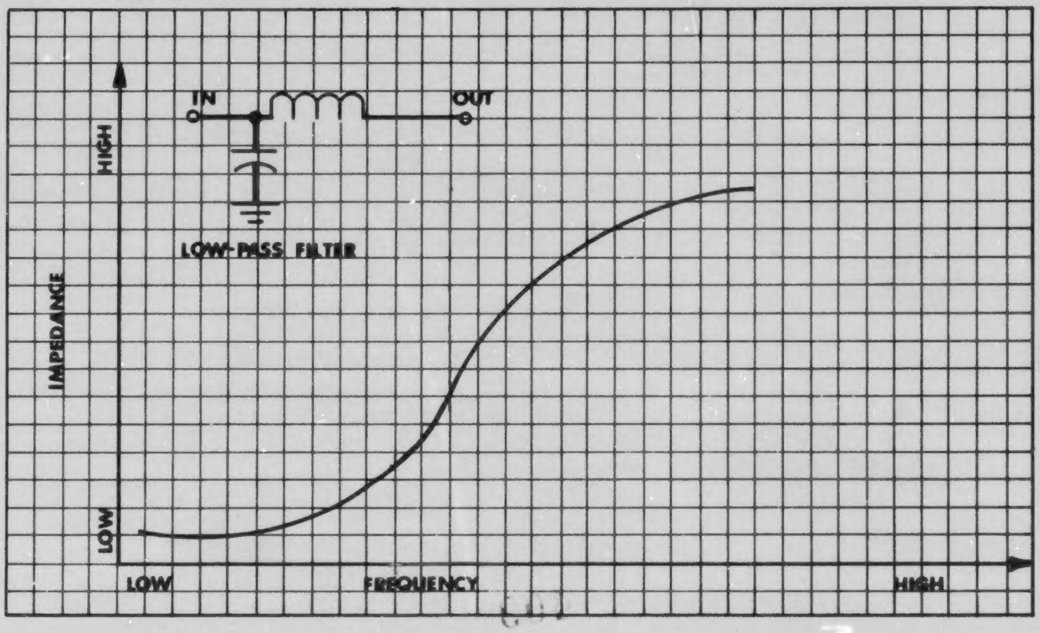
G. Thyrector — Used to filter high-voltage transients of either polarity

VIII. Filters classified according to their functions (Figures 7-10; Transparencies #6-#9; Assignment Sheet #1)

A. Low-pass — Passes lower range of frequencies and impedes higher range (Transparency #6)

EXAMPLE: The frequency and impedance relationship for a typical low-pass filter is shown in Figure 7.

FIGURE 7

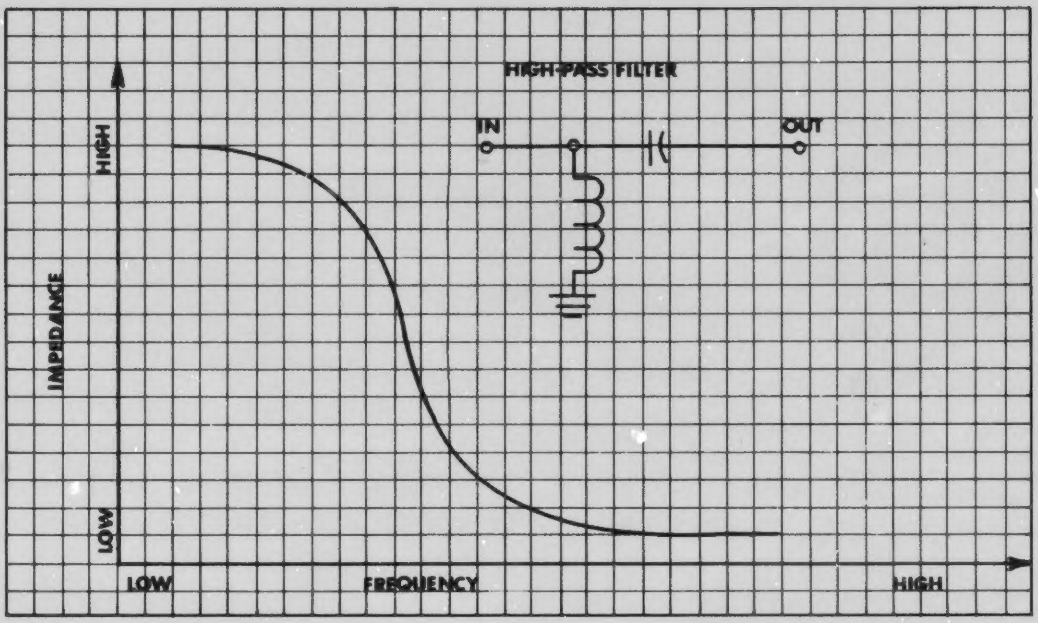


INFORMATION SHEET

B. High-pass — Passes higher range of frequencies and impedes lower range (Figure 8; Transparency #7)

EXAMPLE:

FIGURE 8


HIGH-PASS FILTER
IN
OUT
HIGH
IMPEDANCE
LOW
LOW
FREQUENCY
HIGH

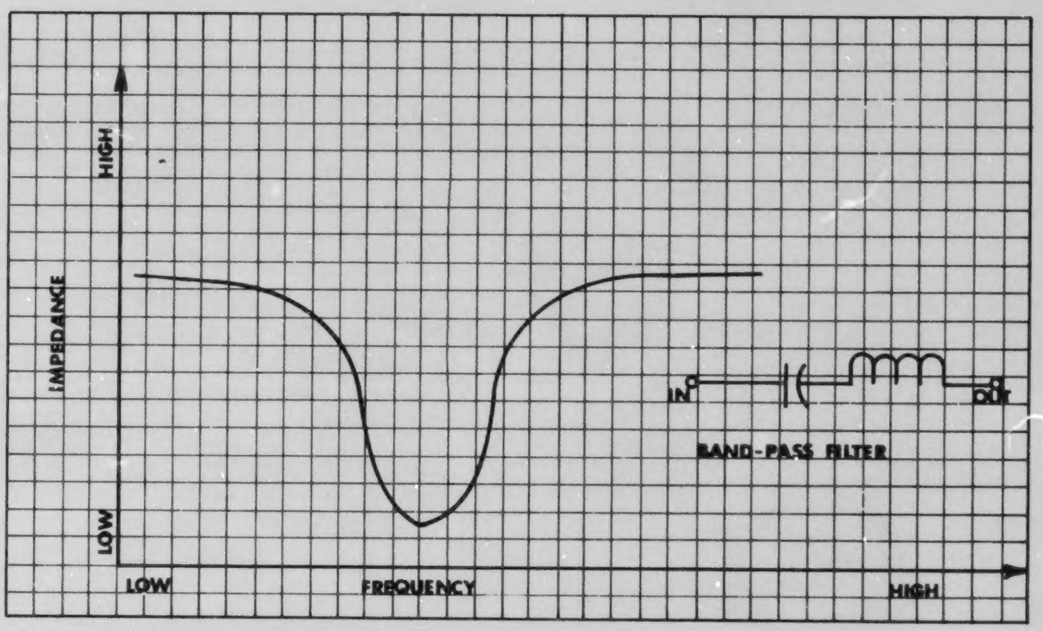
INFORMATION SHEET

C. Band-pass — Passes a band of frequencies and impedes those frequencies above and below that range (Transparency #8)

(NOTE: Remember that capacitors pass high frequencies with less impedance, and inductors pass low frequencies with less impedance. The two in series will thus restrict the low because of the capacitor, and restrict the high because of the choke, without restricting the middle band as much. See Figure 9.)

EXAMPLE:

FIGURE 9



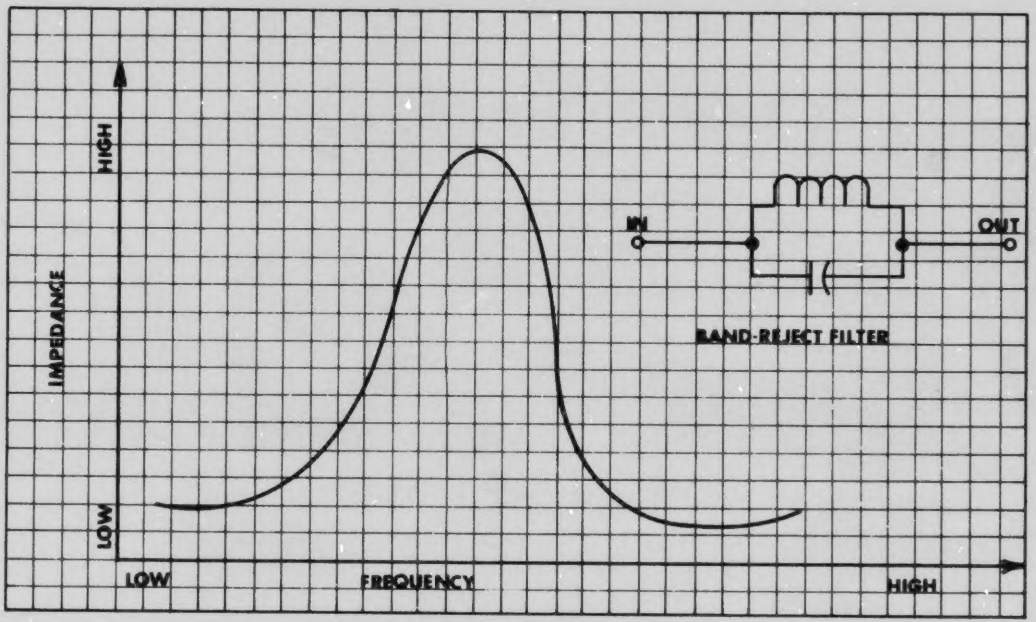
INFORMATION SHEET

D. Band-reject — Passes all frequencies except a range that is impeded (Transparency #9)

(NOTE: The circuit shown having a capacitor and choke in parallel is called a *tank circuit*. At its resonant frequency, its external impedance is extremely high, and it tends to oscillate between the two components at that frequency. See Figure 10.)

EXAMPLE:

FIGURE 10



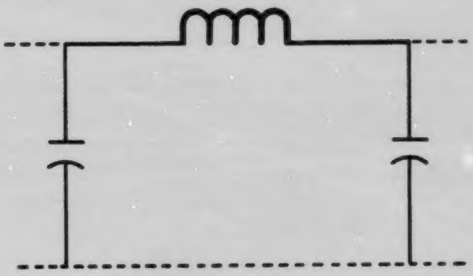
INFORMATION SHEET

IX. Filter configurations (Figures 11-15)

A. π type

(NOTE: The π filter shown is a low-pass filter that is often used for power supplies to filter ripple after rectification. Filters are often referred to according to the components used: RC, LC, LCR, or LR.)

FIGURE 11



Low-Pass LC Filter

B. L type

FIGURE 12

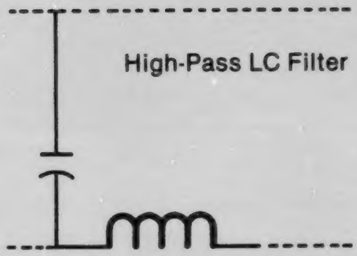
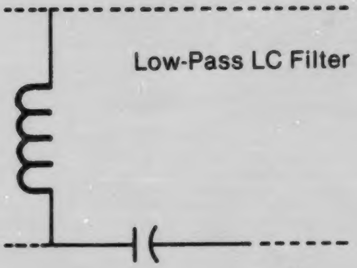

High-Pass LC Filter

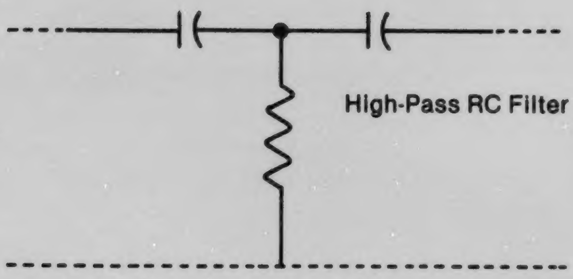
FIGURE 13


Low-Pass LC Filter

INFORMATION SHEET

C. T type

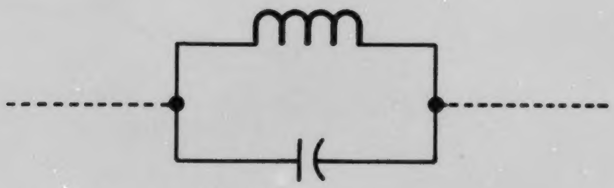
FIGURE 14



D. Band-reject type

(NOTE: A band-reject filter may also be called a *tank circuit* or *wave trap*, depending on its application. Notice that the double-tuned transformer shown in Section VII is actually two tank circuits, but in this arrangement only the resonant frequency is transferred from input to output.)

FIGURE 15



X. Component oppositions to power transfer

(NOTE: The phrase *oppositions to power transfer* is used to distinguish between simply opposing current flow and opposing power transfer)

A. Resistor

1. DC opposition is equal to resistance
2. AC opposition is equal to resistance

B. Capacitor

1. DC opposition is infinite
2. AC opposition decreases as frequency increases

INFORMATION SHEET

C. Inductor

1. DC opposition is equal to conductor resistance and is very low
2. AC opposition increases as frequency increases

XI. Calculating reactance

(NOTE: Information Sheet Sections XI through XV give specific formulas for calculating reactance, impedance, frequency, percent of ripple, and component values. Transparencies #2 and #3 and Transparencies #6-#9 cover other methods and formulas in different circuits.)

A. Capacitive reactance — Use the formula

$$X_C = \frac{1}{2\pi fC}$$

where

X_C = capacitive reactance
f = frequency
C = capacitance

EXAMPLE: A 50-microfarad capacitor operating at 500 hertz

$$X_C = \frac{1}{2\pi fC}$$

$$= \frac{1}{2\,(3.14)\,(500)\,(50 \times 10^{-6})}$$

$$= \frac{1}{6.28 \times 5 \times 5 \times 10^{-3}}$$

$$= \frac{1}{6.28 \times 25} \times 10^{3}$$

$$= \frac{1}{157} \times 10^{3}$$

$$= 0.0064 \times 10^{3}$$

$$= 6.4\ \Omega$$

INFORMATION SHEET

B. Inductive reactance — Use the formula

$$X_L = 2\pi fL$$

where

X_L = inductive reactance
f = frequency
L = inductance

EXAMPLE: A 100-millihenry inductor operating at 3 kilohertz

$$X_L = 2\pi fL$$
$$= 2(3.14)(3 \times 10^3)(100 \times 10^{-3})$$
$$= 6.28 \times 300$$
$$= 1{,}884\ \Omega$$

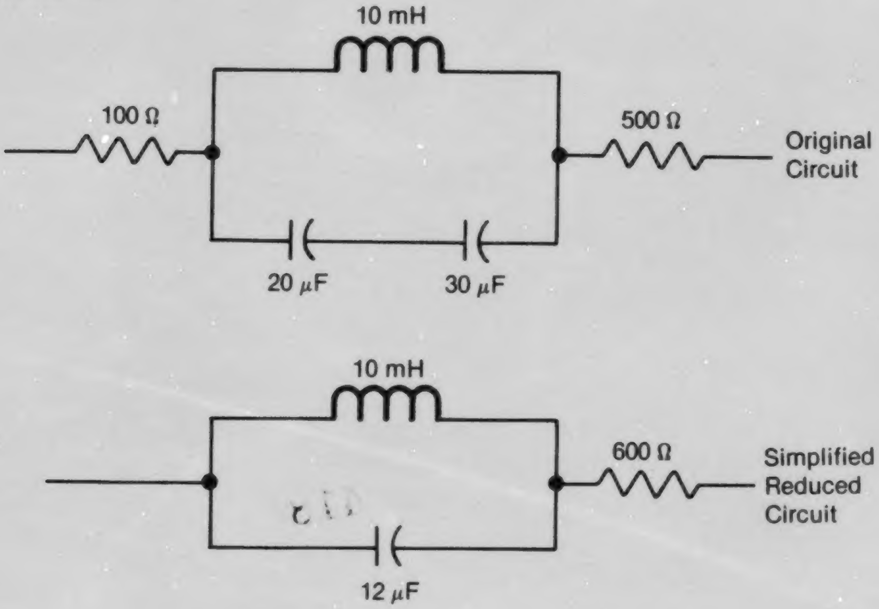
XII. Calculating impedance (Transparencies #2 and #3)

A. Reduce circuit to simplest form (Figure 16)

(NOTE: Review previous units of instruction, or refer to a good basic electronics text if necessary in order to simplify circuits. Much more complicated methods exist, but these are not usually required by technicians.)

EXAMPLE:

FIGURE 16


10 mH
100 Ω
500 Ω
Original Circuit
20 μF
30 μF
10 mH
600 Ω
Simplified Reduced Circuit
12 μF

INFORMATION SHEET

B. Calculate reactance if it is not known

EXAMPLE: For the simplified circuit in Figure 16 where frequency is 4 kilohertz —

$$X_L = 2\pi fL$$

$$= 2\,(3.14)\,(4 \times 10^3)\,(10 \times 10^{-3})$$

$$= 6.28 \times 4 \times 10$$

$$= 6.28 \times 40$$

$$= 251.2\ \Omega$$

$$= 251\ \Omega$$

$$X_C = \frac{1}{2\pi fC}$$

$$= \frac{1}{2\,(3.14)\,(4 \times 10^3)\,(12 \times 10^{-6})}$$

$$= \frac{1}{(6.28)\,(4 \times 12 \times 10^{-3})}$$

$$= \frac{1}{6.28 \times 48 \times 10^{-3}}$$

$$= \frac{1}{6.28 \times 48} \times 10^3$$

$$= \frac{1}{301.44} \times 10^3$$

$$= 0.0033 \times 10^3$$

$$= 3.3\ \Omega$$

INFORMATION SHEET

C. Calculate the impedance for the circuit configuration

EXAMPLE: For the simplified circuit in Figure 16 — Use the formula

$$Z = \frac{X_L \times X_C}{X_L - X_C} + R$$

where

Z = impedance
X_L = inductive reactance
X_C = capacitive reactance
R = resistance

$$Z = \frac{251 \times 3.3}{251 - 3.3} + 600$$

$$= \frac{828.3}{247.7} + 600$$

$$= 3.3 + 600$$

$$= 603.3\ \Omega$$

(NOTE: The capacitor and inductor had little effect at this frequency.)

XIII. Calculating frequency of resonance — Use the formula

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

where

f_r = resonant frequency
L = inductance
C = capacitance

(NOTE: A tank circuit has its highest external impedance at resonance. If the following circuit operates at 460 hertz, its impedance will be theoretically at infinity. You may want to calculate the impedance for the circuit of Section XII at this frequency.)

INFORMATION SHEET

EXAMPLE: For the problem worked out previously in Section XII —

$$
\begin{aligned}
f_r &= \frac{1}{2\pi\sqrt{LC}} \\
&= \frac{1}{2\pi\sqrt{10 \times 10^{-3} \times 12 \times 10^{-6}}} \\
&= \frac{1}{2\pi\sqrt{10 \times 12 \times 10^{-9}}} \\
&= \frac{1}{2\pi\sqrt{120 \times 10^{-9}}} \\
&= \frac{1}{2\pi\sqrt{12 \times 10^{-8}}} \\
&= \frac{1}{2\pi\sqrt{12} \times 10^{-8 \div 2}} \\
&= \frac{1}{2\pi\, 3.46 \times 10^{-4}} \\
&= \frac{1}{6.28 \times 3.46} \times 10^{4} \\
&= \frac{1}{21.73} \times 10^{4} \\
&= 0.0460 \times 10^{4} \\
&= 460 \text{ Hz}
\end{aligned}
$$

XIV. Calculating percentage of ripple for filter circuits (Transparency #4)

A. Determine root mean square value of ripple effect — Use the formula

$$\text{rms ripple} = \frac{\text{pk} - \text{pk}}{2} \times 0.707$$

where

rms = root mean square
pk − pk = peak-to-peak

(NOTE: The constant 0.707 is the square root of the average, or mean, of all the squared values of the sine wave.)

INFORMATION SHEET

EXAMPLE: A 100-volt, zero-to-peak voltage supply has a 10-volt peak-to-peak pulsating waveform (ripple) component; see Figure 17.

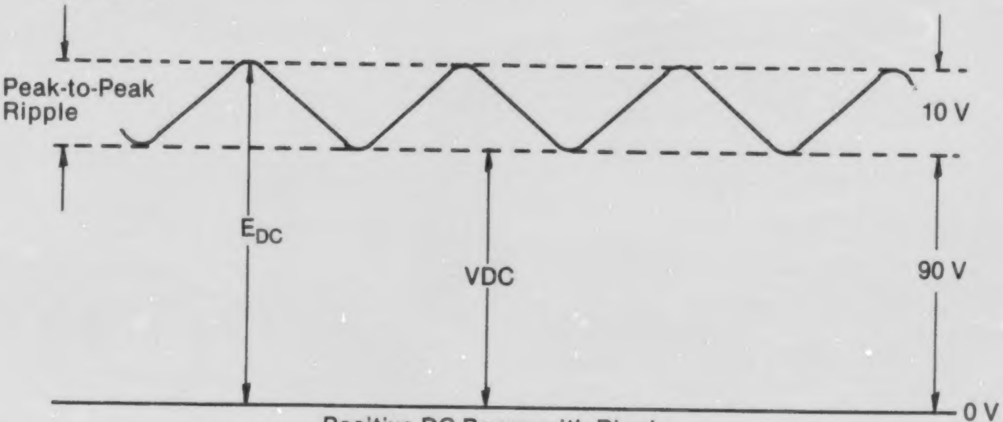
$$\text{rms ripple} = \frac{\text{pk-pk}}{2} \times 0.707$$

$$= \frac{10}{2} \times 0.707$$

$$= 5 \times 0.707$$

$$= 3.535 \text{ V}$$

FIGURE 17



Positive DC Power with Ripple

(NOTE: Figure 17 represents 90 volts of constant DC with a 10-volt, peak-to-peak DC pulsation.)

B. Determine approximate average DC voltage — Use the formula

$$E_{ave} = \frac{E_{DC} + VDC}{2}$$

where

E_{ave} = average voltage
E_{DC} = direct current voltage
VDC = steady direct current

EXAMPLE:

$$E_{ave} = \frac{E_{DC} + VDC}{2}$$

$$= \frac{100 + 90}{2}$$

$$= \frac{190}{2}$$

$$= 95 \text{ V}$$

INFORMATION SHEET

C. Calculate the percentage — Use the formula

$$\% \text{ ripple} = \frac{\text{rms ripple}}{E_{ave}} \times 100$$

where

% ripple = percent of ripple voltage
rms ripple = root mean square of ripple voltage
E_{DC} = average value of total voltage

$$\% \text{ ripple} = \frac{\text{rms ripple}}{E_{ave}} \times 100$$

$$= \frac{3.535}{95} \times 100$$

$$= 0.037 \times 100$$

$$= 3.7\%$$

XV. Calculating component values in filtering circuits (Transparencies #5-#9; Assignment Sheet #2)

A. Decide which frequency response curve is suitable

B. Decide which filter configuration is applicable or preferred

C. Find inductive or capacitive reactance when given frequencies and load resistance — Use the appropriate formula according to the filter configuration

EXAMPLE: A filter is needed to connect a low-frequency control signal to a servo amplifier with a 100-ohm input resistance. The maximum control signal frequency is 1,000 hertz. What should be the component size for a π filter to screen out high-frequency noise? The correct type of filter is a low-pass. The π filter for the low-pass function has the following equations (Transparency #6):

$$L = \frac{R}{\pi f_C}$$

where

L = inductance
R = resistance
f_c = frequency cutoff

and

$$C = \frac{1}{2\pi f_c R}$$

Where C = capacitance
f_c = frequency cutoff
R = resistance

R is 100 ohms and f_c is 1 kilohertz given in the problem —

$$L = \frac{R}{\pi f_c}$$

$$= \frac{100}{3.14 \times 1 \times 10^3}$$

$$= \frac{100}{3.14} \times 10^{-3}$$

$$= 31.8 \text{ mH}$$

(NOTE: If the wrong filter is selected, the values of the components will not be realistic.)

$$C = \frac{1}{2\pi f_c R}$$

$$= \frac{1}{2\,(3.14)\,(1 \times 10^3)\,(100)}$$

$$= \frac{1}{6.28 \times 100} \times 10^{-3}$$

$$= \frac{1}{628} \times 10^{-3}$$

$$= 0.00159 \times 10^{-3}$$

$$= 1.59 \times 10^{-6}$$

$$= 1.59\ \mu\text{F}$$

D. Determine proper working voltages for capacitors and proper current-carrying capabilities for inductors

(NOTE: In resonant circuits, there is a resonant rise in voltage and current at the resonant frequency. Be sure that the components selected have the proper voltage and current ratings.)

INFORMATION SHEET

XVI. Sources of electrical noise

- A. Poor power supply filtering

  EXAMPLES: Defective filter components, defective rectification, poor design

- B. Natural sources

  EXAMPLE: Lightning

- C. Electrical equipment

  EXAMPLES: Automobile ignitions, motors, thyristor controls, televisions, computers, radios, microwaves

- D. Defective equipment

  EXAMPLES: Loose high-current electrical connectors act as noise transmitters; defective electronic circuits can oscillate or generate noise.

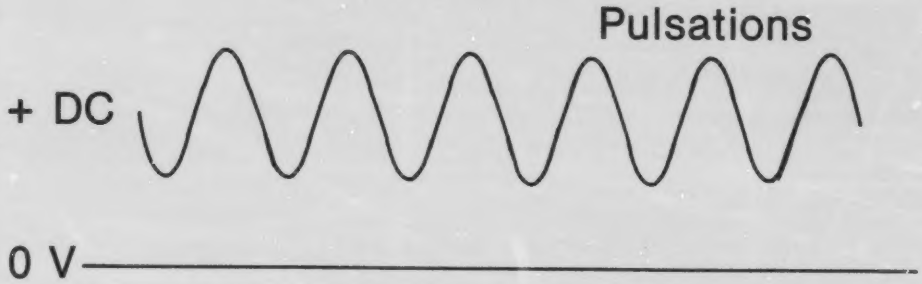
- E. Improperly maintained equipment

  EXAMPLES: Poorly tuned equipment, overdriven amplifiers, equipment improperly covered (lids, doors), or poorly grounded

  (NOTE: It is the responsibility of all electronics technicians to guard against poor maintenance practices that could result in the transmission of electromagnetic or electrical noise [static]. Manufacturers of electrical equipment must meet requirements for noise such as those of the FCC or FAA. Users of equipment [industry] can be cited for generating radio interference that can disturb essential transmission for aircraft or police, or disrupt communications such as telephone, radio, and television.)

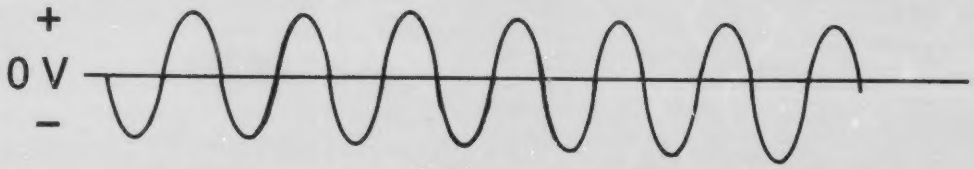
AC and DC Waveforms

DC > AC = Pulsating DC



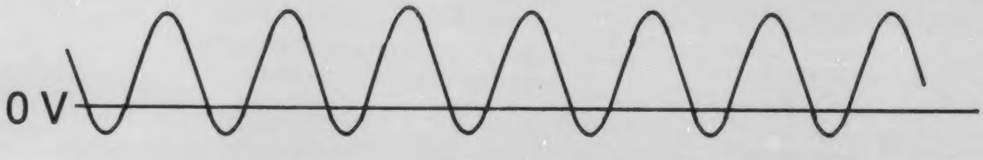
All Current Flows in Same Direction

DC = Zero-Balanced AC



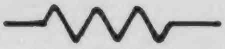
Current Flows Equally in Both Directions

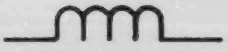
AC > DC = Level-Shifted AC

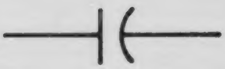


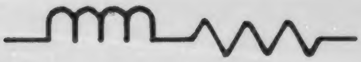
Current Flow Alters Directions but Is Much Greater in One Direction

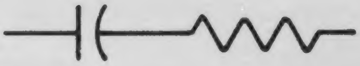
Impedance Formulas

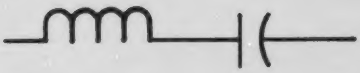

$Z = R =$ Resistance


$Z = 2\pi fL =$ Inductive Reactance, X_L

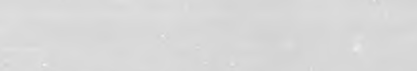

$Z = \dfrac{1}{2\pi fC} =$ Capacitive Reactance, X_C


$Z = \sqrt{R^2 + X_L{}^2}$


$Z = \sqrt{R^2 + X_C{}^2}$

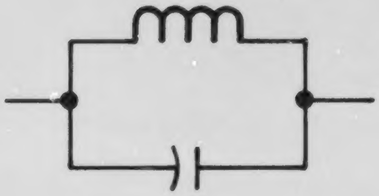

$Z = X_L - X_C$, if $X_L > X_C$

$Z = X_C - X_L$, if $X_C > X_L$

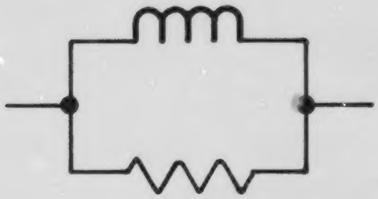

$Z = \sqrt{R^2 + (X_L - X_C)^2}$

Impedance Formulas

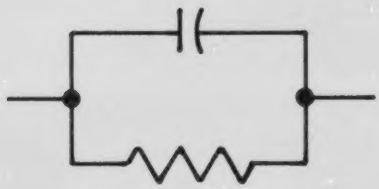
(Continued)



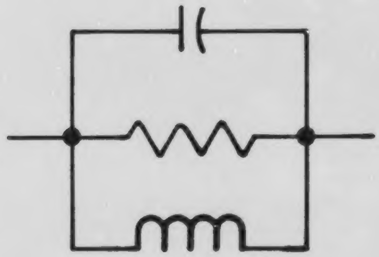
$$Z = \frac{X_L X_C}{X_L - X_C}$$ (depending on which is larger)



$$Z = \frac{RX_L}{\sqrt{R^2 + X_L^2}}$$

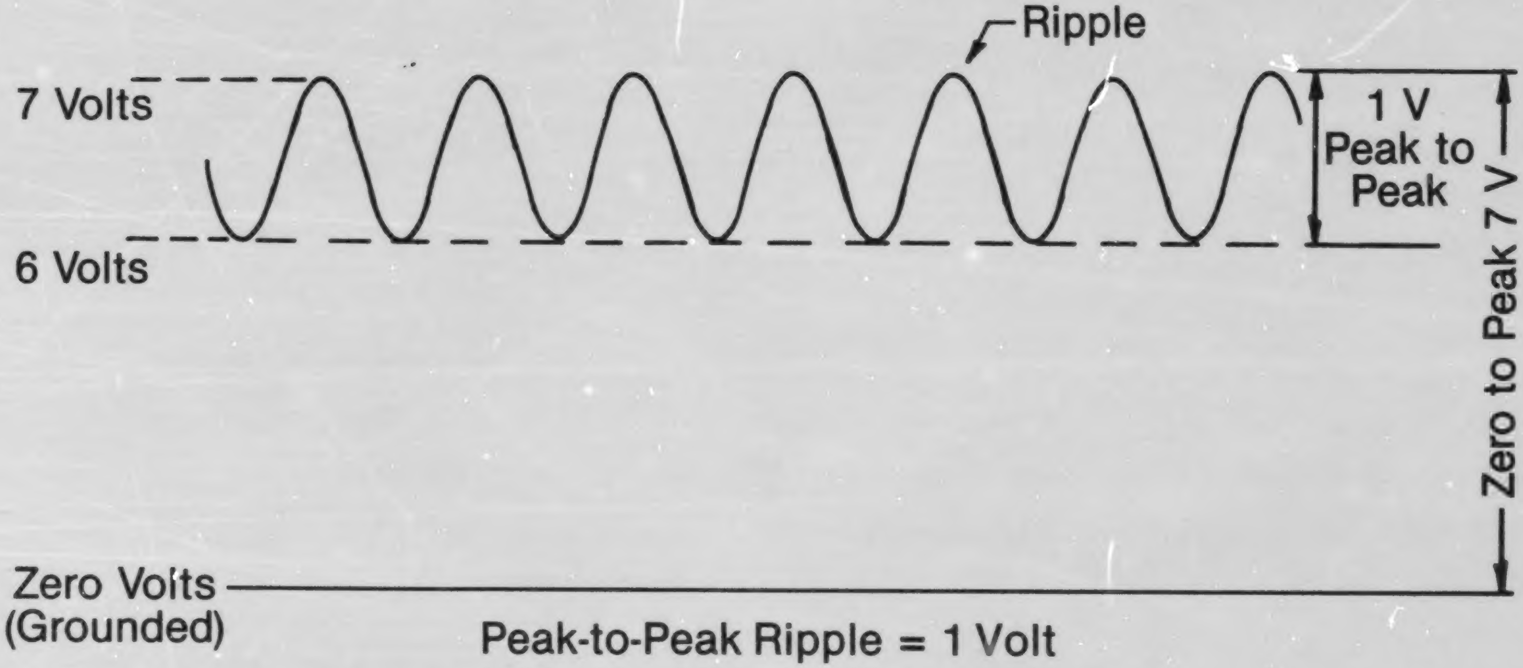


$$Z = \frac{RX_C}{\sqrt{R^2 + X_C^2}}$$



$$Z = \frac{R X_L X_C}{\sqrt{X_L^2 X_C^2 + R^2 (X_L - X_C)^2}}$$

Power Supply Ripple


Ripple
7 Volts
6 Volts
1 V Peak to Peak
Zero to Peak 7 V
Zero Volts (Grounded)

Peak-to-Peak Ripple = 1 Volt

Zero-to-Peak Voltage (E_{DC}) = 7 Volts

Steady DC (VDC) = 6 Volts

rms Ripple = 0.35 Volts

Percent Ripple = 5%

Bandwidth and Quality

NOTES

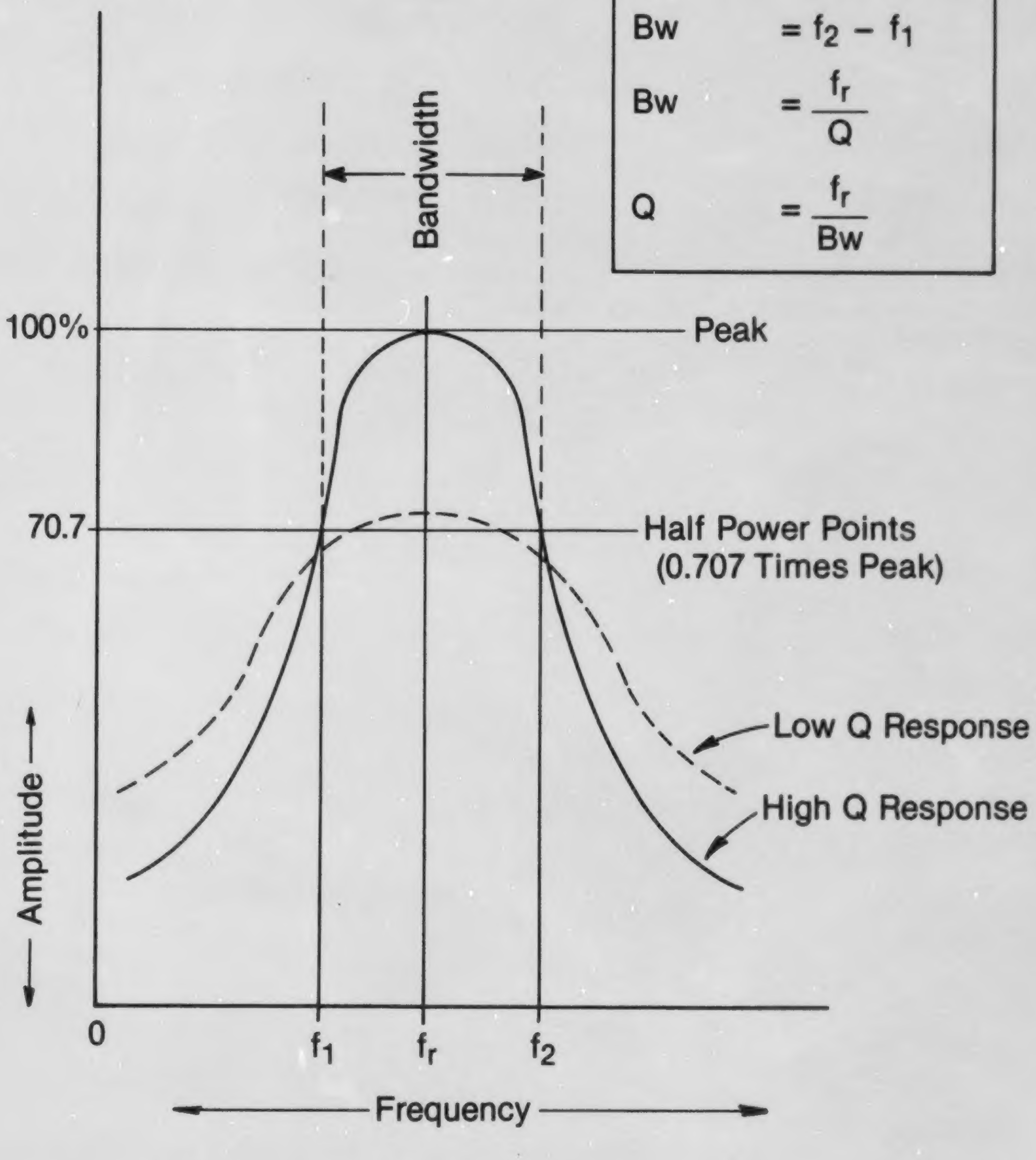
High Q = Narrow Bw

Low Q = Wide Bw

Bw $= f_2 - f_1$

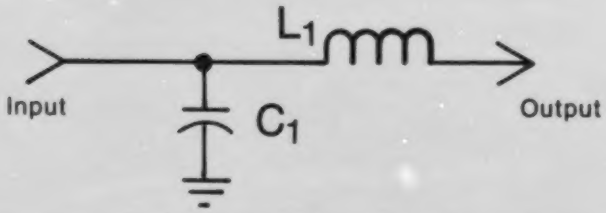
Bw $= \dfrac{f_r}{Q}$

Q $= \dfrac{f_r}{Bw}$


Bandwidth
100%
Peak
70.7
Half Power Points
(0.707 Times Peak)
Low Q Response
High Q Response
Amplitude
0
f_1
f_r
f_2
Frequency

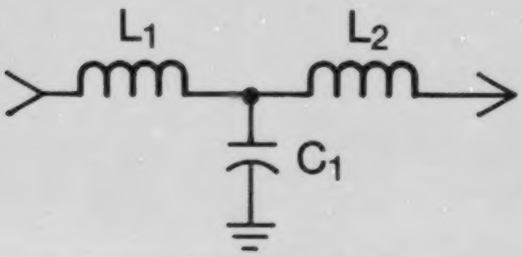
Low-Pass Filters

R = Load Resistance


L1
Input
C1
Output

$$L_1 = \frac{R}{\pi f_C}$$

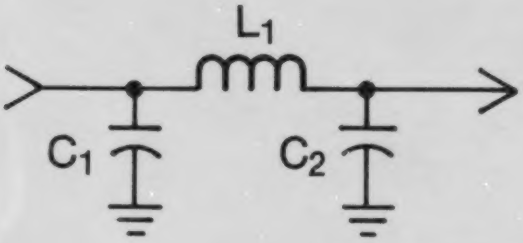
$$C_1 = \frac{1}{\pi f_C R}$$



$$L_1 = \frac{R}{2\,\pi f}$$

$$L_2 = \frac{R}{2\,\pi f}$$

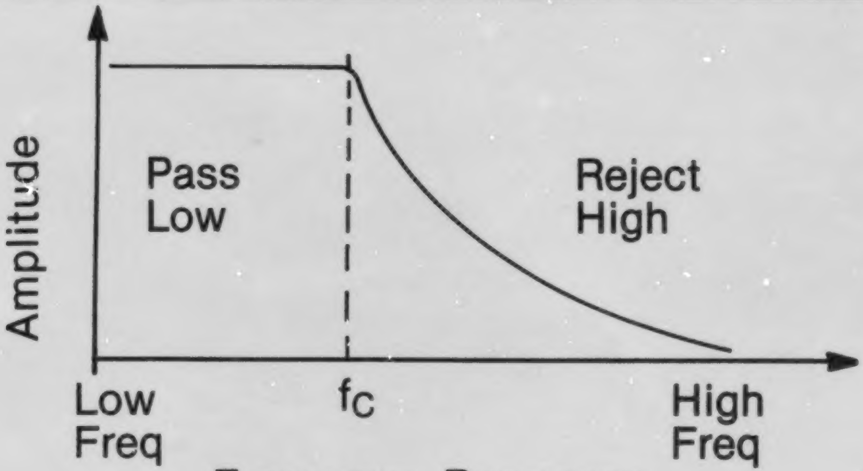
$$C_1 = \frac{1}{\pi f_C R}$$



$$L_1 = \frac{R}{\pi f_C}$$

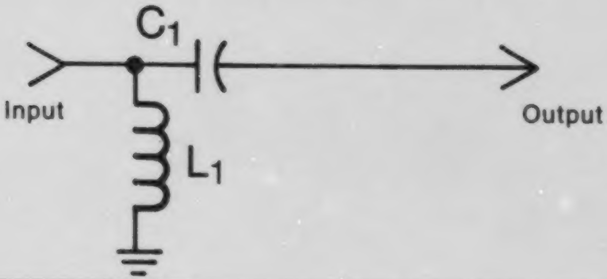
$$C_1 = \frac{1}{2\,\pi f_C R}$$

$$C_2 = \frac{1}{2\,\pi f_C R}$$



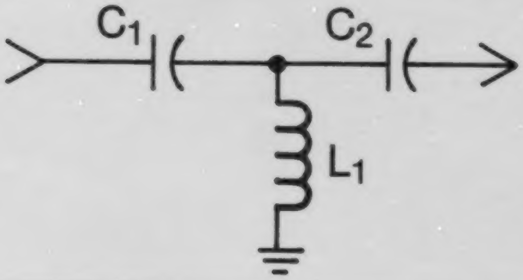
Frequency Response

High-Pass Filters


C1
Input
Output
L1

$$C_1 = \frac{1}{4\pi f_C R}$$

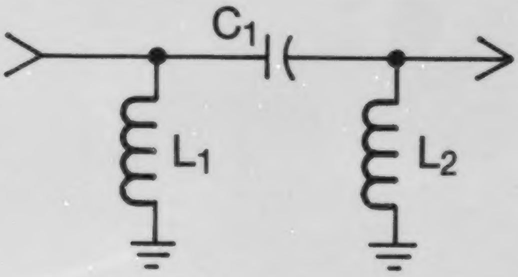
$$L_1 = \frac{R}{4\pi f_C}$$



$$C_1 = \frac{1}{2\pi f_C R}$$

$$C_2 = \frac{1}{2\pi f_C R}$$

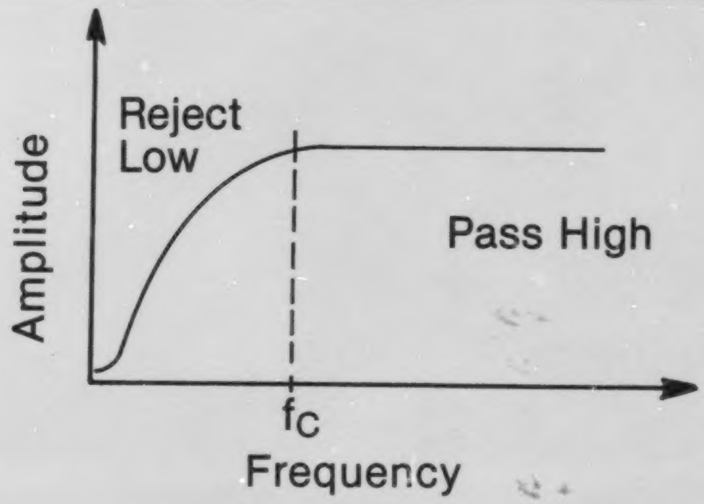
$$L_1 = \frac{R}{4\pi f_C}$$



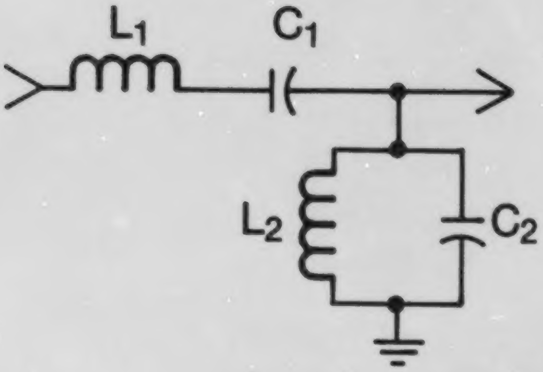
$$C_1 = \frac{1}{4\pi f_C R}$$

$$L_1 = \frac{R}{2\pi f_C}$$

$$L_2 = \frac{R}{2\pi f_C}$$



Band-Pass Filters

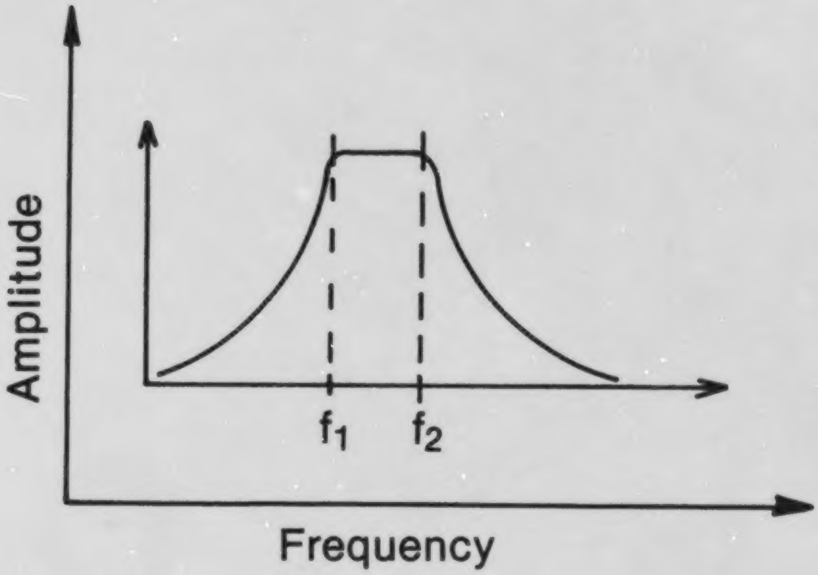


$$L_1 = \frac{R}{\pi (f_2 - f_1)}$$

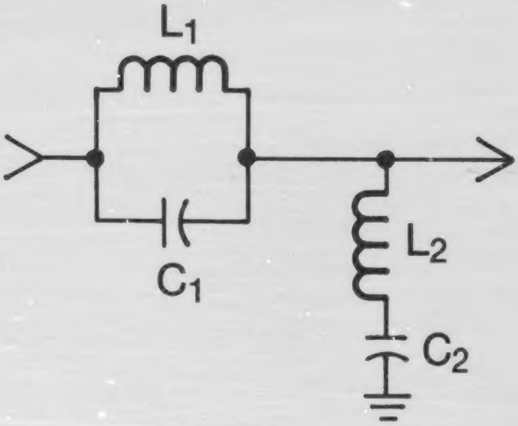
$$L_2 = \frac{(f_2 - f_1) R}{4 \pi f_1 f_2}$$

$$C_1 = \frac{f_2 - f_1}{4 \pi f_2 f_1 R}$$

$$C_2 = \frac{1}{\pi (f_2 - f_1) R}$$



Band-Reject Filters

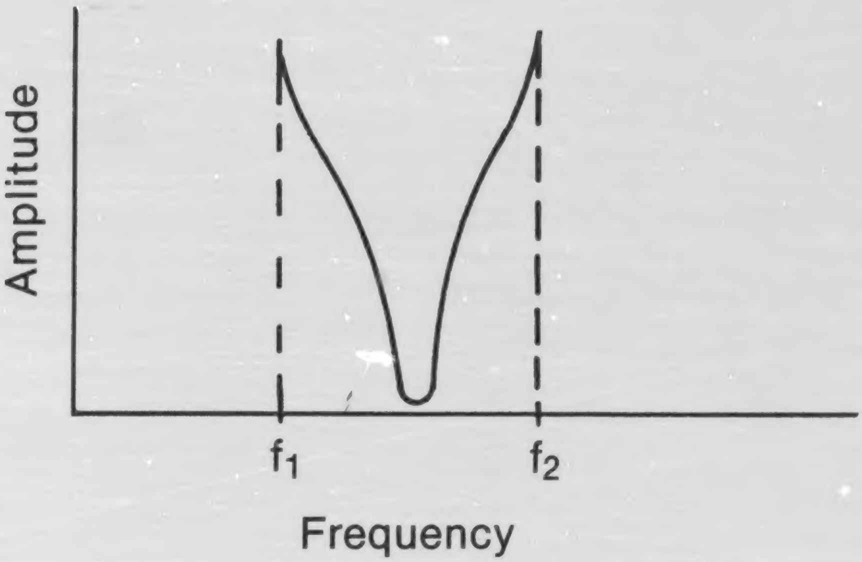


$$L_1 = \frac{(f_2 - f_1)\,R}{\pi f_1 f_2}$$

$$L_2 = \frac{R}{4\pi(f_2 - f_1)}$$

$$C_1 = \frac{1}{4\pi(f_2 - f_1)\,R}$$

$$C_2 = \frac{f_2 - f_1}{\pi f_1 f_2 R}$$



Radio-Frequency Applications

Radio Frequency: (Hertz)	30 k	300 k	3 M	30 M	300 M	3 G	30 G	300 G
Bands:	VLF	LF	MF	HF	VHF	UHF	SHF	EHF
Typical Applications **Broadcast:**	Radio Telegraphy	AM Radio	AM Radio Marine Radio	Amateur (Ham) Radio Broadcast Short Wave Radio Citizens Band (CB) Ham Radio Low Police Band	VHF Television FM Radio, Ham Radio VHF Aircraft High Police Band Weather	UHF Television Radar, Low Frequency	Microwave Satellite Signals	Radar, High Frequency C and X Bands

FILTERING CIRCUITS
UNIT III

ASSIGNMENT SHEET #1 — CALCULATE COMPONENT VALUES FOR FILTER CIRCUITS

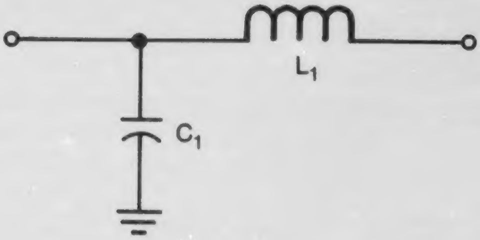
NAME ______________________________ SCORE ______________

As an electronics technician, there will be times when you must determine the size of components necessary for certain filter requirements for design, repair, or verification of values. For this reason you should be familiar with the procedures necessary to determine the correct component values.

In the following problems, calculate the values of the components required for the filters illustrated. Show your work.

A. It is necessary that all frequencies from 652 kilohertz and up be filtered out or blocked for a circuit that has an 8-kohm output or load impedance. What are the values of the components in the filter shown below?

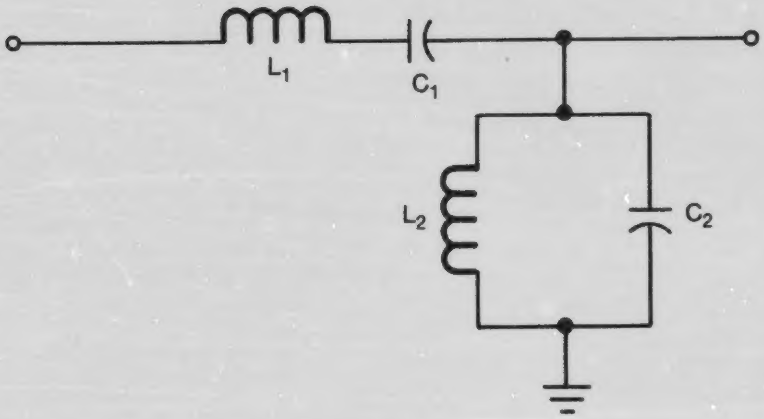
1. L1 = ______________
2. C1 = ______________



ASSIGNMENT SHEET #1

B. A filter must be built that will reject all frequencies except those from 10 through 20 kilohertz. The signal must be applied to a load with a resistance of 120 ohms. What are the values of the components in the filter shown below?

1. L1 = ____________________
2. L2 = ____________________
3. C1 = ____________________
4. C2 = ____________________



FILTERING CIRCUITS
UNIT III

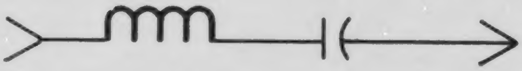
ASSIGNMENT SHEET #2 — DETERMINE FILTER EFFECTS ON VARIOUS FREQUENCY BANDS

NAME ____ SCORE ________________

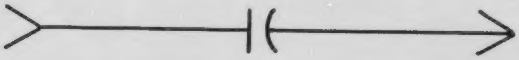
An electronics technician must be able to determine the effects that various components or combinations of components will have on different circuits.

Of the components shown below, indicate which of the frequencies will be passed and which will be blocked. Write the correct numbers in the space provided. Each blank will have more than one answer.

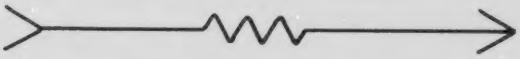
_____A.



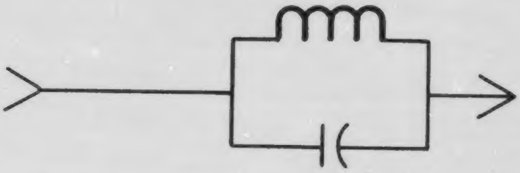
_____B.



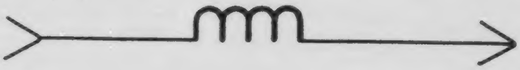
_____C.



_____D.



_____E.



1. Pass all
2. Pass high
3. Pass low
4. Pass f_r
5. Block all
6. Block high
7. Block low
8. Block f_r
9. Block none
10. Block high and low
11. Pass high and low

FILTERING CIRCUITS
UNIT III

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

A. 1. L1 = 3.9 mH

2. C1 = 61 pF

B. 1. L1 = 3.8 mH

2. L2 = 0.48 mH

3. C1 = 0.033 μF

4. C2 = 0.27 μF

Assignment Sheet #2

A. 4, 6, 7, 10

B. 2, 7

C. 1, 9, 11

D. 2, 3, 8, 11

E. 3, 6

FILTERING CIRCUITS
UNIT III

JOB SHEET #1 — ANALYZE VARIOUS LC FILTERS

I. Equipment and materials

  A. Capacitor, 10 microfarad, 25 volt

  B. Inductor, 10 to 50 millihenry

  C. Sine-wave oscillator or signal generator, output range from at least 20 hertz to 10 kilohertz

  D. Dual-trace oscilloscope with two probes

  E. Two sheets of graph paper or quad-ruled paper

  F. Resistor, 10 kohm, 1/4 or 1/2 watt

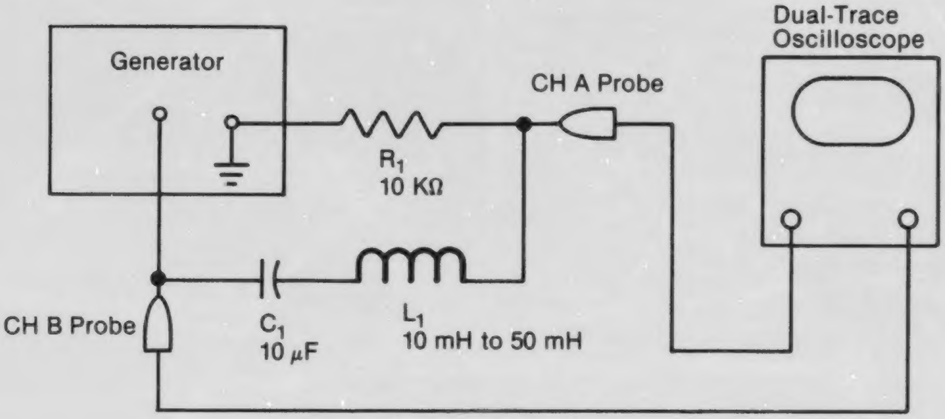
  G. Breadboard

II. Procedure

  A. Construct circuit as shown in Figure 18

  (NOTE: Have instructor check circuit before proceeding.)

FIGURE 18


Dual-Trace Oscilloscope
Generator
CH A Probe
R_1
10 KΩ
CH B Probe
C_1
10 μF
L_1
10 mH to 50 mH

Series LC Circuit

  B. To reduce interference, connect one oscilloscope probe ground clip to generator ground lead

  C. Set oscilloscope for proper two-channel operation

  D. Set generator output for about one volt peak-to-peak

JOB SHEET #1

E. Start at a very low frequency and adjust generator frequency over a wide range

(NOTE: The output of the generator [Channel B] should not vary amplitude much as the frequency is changed, but the output of the LC circuit [Channel A] amplitude should vary considerably. This is an indication of frequency response.)

F. Find the frequency where the circuit output peaks

(NOTE: This is the resonant frequency. Some circuits have lesser peaking frequencies above and below the resonant. These are called *harmonics.*)

G. Mark resonant frequency on graph in Figure 18 under "f_r"; mark each major division to left in increments of 1 kilohertz decreasing; mark each major division to right in increments of 1 kilohertz increasing

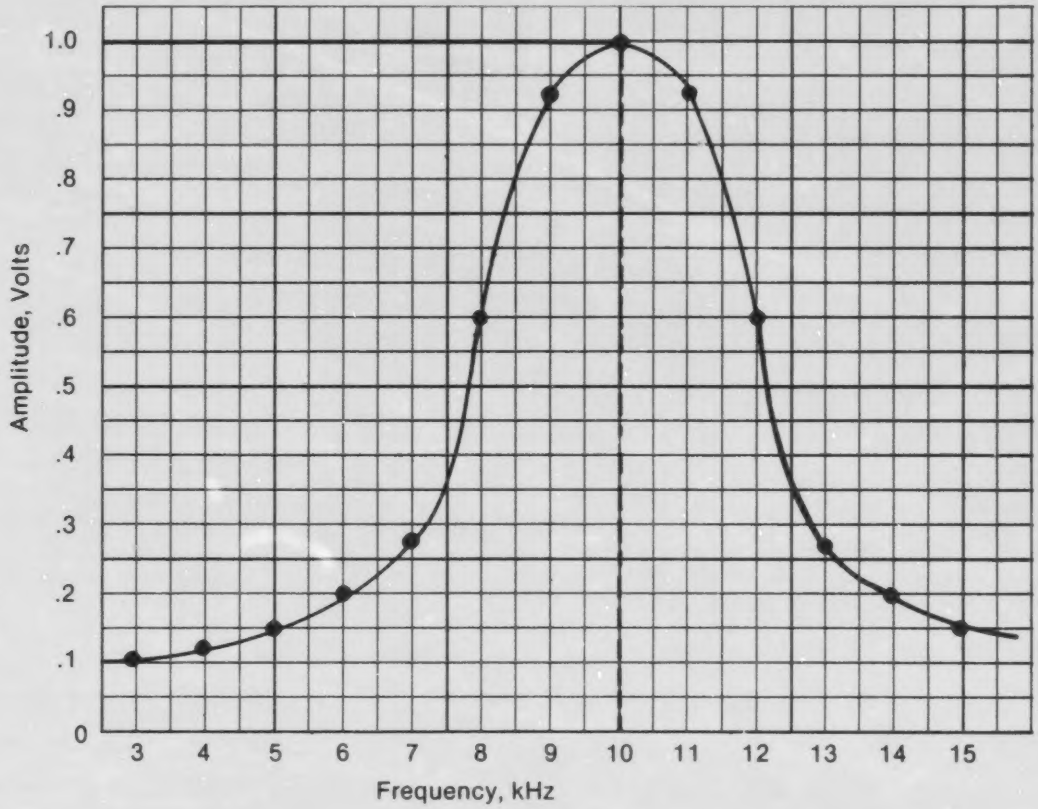
H. With generator frequency at f_r, adjust amplitude for a 1.0-volt peak-to-peak signal at output of LC circuit (CH A)

I. Set generator frequency to each frequency value labeled on graph in Figure 18, one at a time, and measure amplitude

J. Plot these points on graph in Figure 20

(NOTE: The resulting graph is a frequency response curve. The frequency range lies between the 0.707 points of the waveform. See Figure 19 below.)

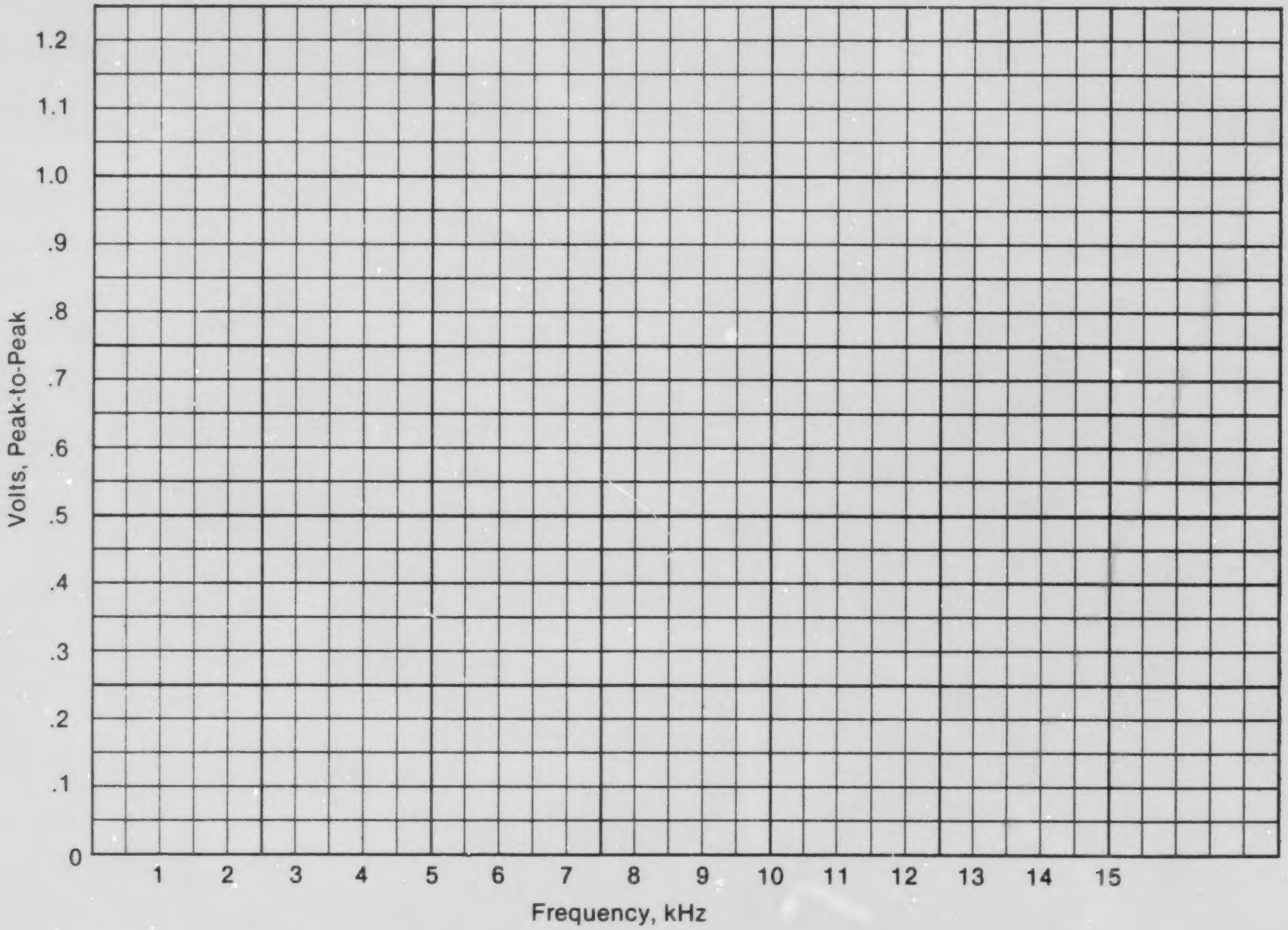
FIGURE 19



JOB SHEET #1

FIGURE 20

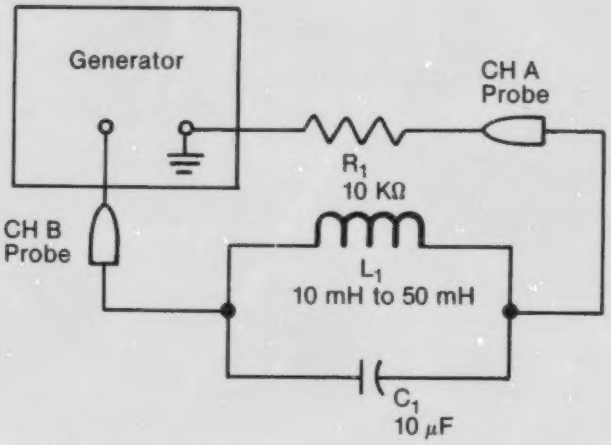
SERIES LC FREQUENCY RESPONSE



JOB SHEET #1

K. Rearrange the LC circuit as shown in Figure 21

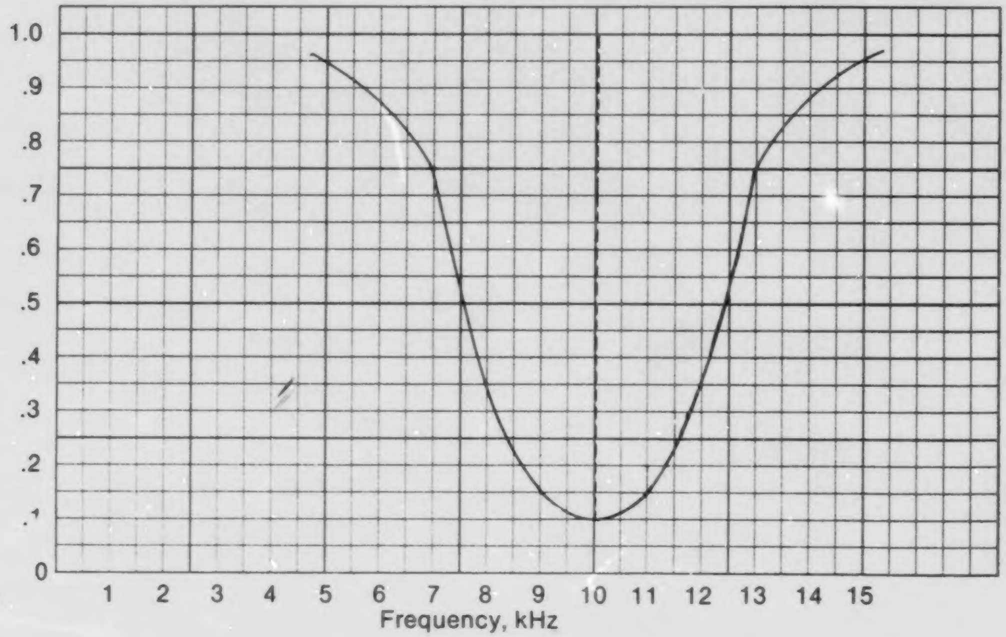
FIGURE 21


Generator
CH A Probe
R_1 10 KΩ
CH B Probe
L_1 10 mH to 50 mH
C_1 10 μF

L. Repeat steps D through J on graph in Figure 22, but make note of the following differences

1. At resonance, the circuit output will dip instead of peak
2. At step H, adjust the generator for a channel A amplitude of 0.1 volts instead of 1.0 volts (Figure 22)

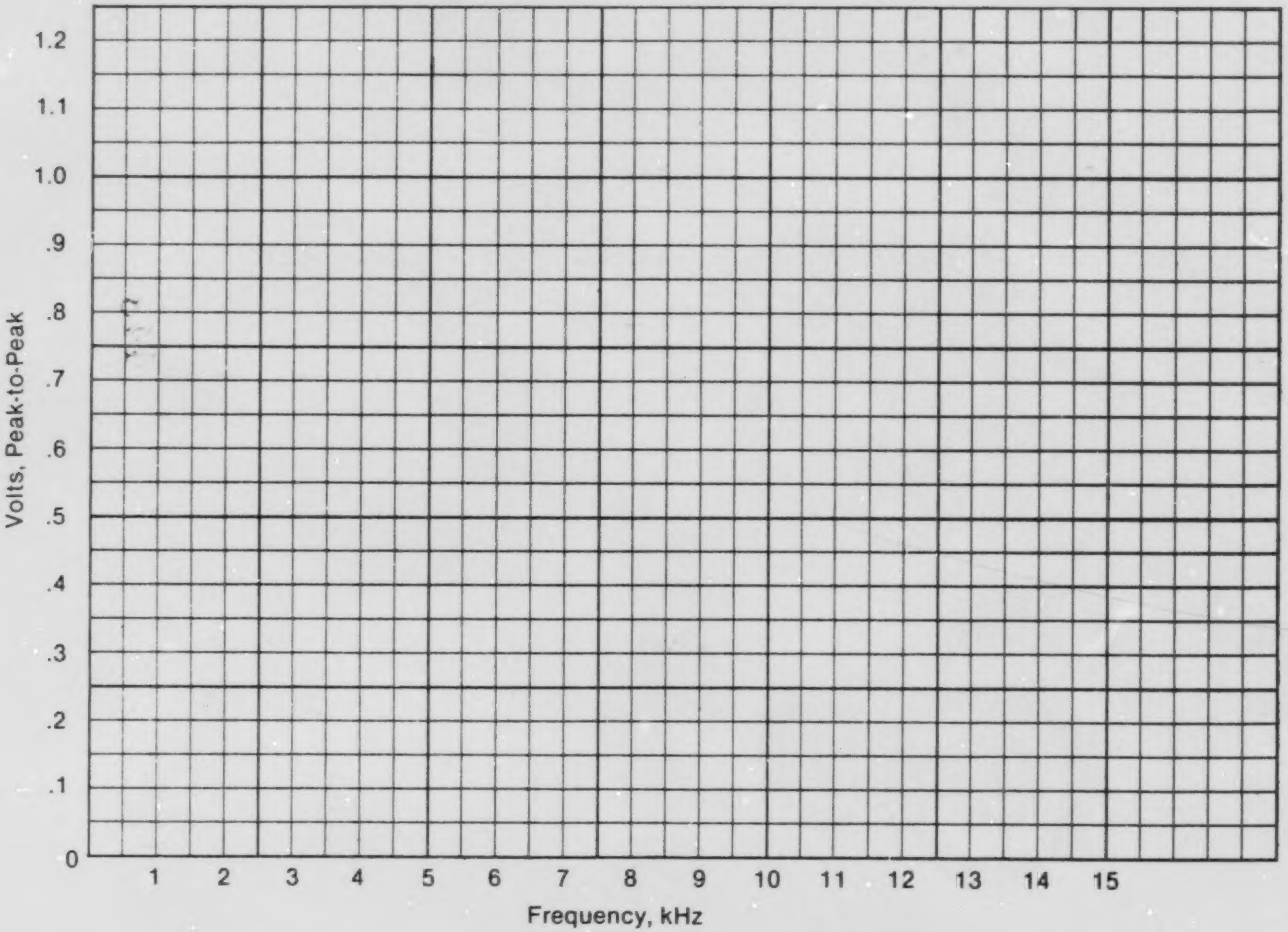
FIGURE 22



JOB SHEET #1

FIGURE 23

PARALLEL LC FREQUENCY RESPONSE



JOB SHEET #1

M. Turn off equipment

N. Clean work area and put away equipment and materials

FILTERING CIRCUITS
UNIT III

JOB SHEET #2 — ANALYZE CAPACITIVE FILTER CIRCUITS

I. Equipment and materials

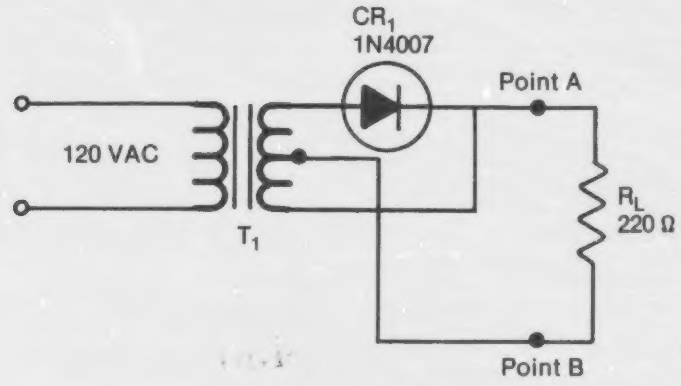
- A. Low-power transformer, 120 VAC/12.6 volts center tap
- B. Two diodes, 1N4007 or equivalent
- C. Resistor, 220 ohm, 1 watt
- D. Capacitor, 10 microfarad, 12 volt minimum
- E. Capacitor, 150 microfarad, 12 volt minimum
- F. Capacitor, 300 microfarad, 12 volt minimum
- G. Oscilloscope
- H. Breadboard
- I. Test leads

II. Procedure using half-wave rectifier

- A. Construct circuit as shown in Figure 24

  (NOTE: Have instructor check circuit before proceeding.)

FIGURE 24



JOB SHEET #2

B. Connect oscilloscope across load resistor

C. Measure peak voltage and record

   1. Peak voltage = ______________________

   2. Draw the waveform in the space provided below

D. Turn off power and connect 10-microfarad capacitor to points A and B, observing capacitor polarity

E. Turn on power and draw waveform in the space provided below, recording all voltages

F. Calculate rms of ripple; record below

$$\text{rms ripple} = \frac{\text{pk-pk ripple}}{2} \times 0.707$$

rms ripple = ______________________

JOB SHEET #2

G. Calculate the E_{DC}; record below

E_{DC} = VDC + pk ripple

E_{DC} = ______________________

H. Calculate the percentage of ripple and record below

$$\% \text{ of ripple} = \frac{\text{rms ripple}}{E_{ave}} \times 100$$

% of ripple = ______________________

I. Turn off power and replace the 10-microfarad capacitor with the 150-microfarad capacitor

J. Repeat steps E through H; record below and sketch waveform in the space provided

rms ripple = ____

E_{DC} = ____

% of ripple = ____

JOB SHEET #2

K. Turn off power and replace the 150-microfarad capacitor with the 300-microfarad capacitor

L. Again, repeat steps E through H; record below and sketch waveform in space provided

rms ripple = ______________________________

E_{DC} = ______________________________

% of ripple = ______________________________

M. What occurred each time the capacitors were exchanged?

____

____

N. Should this change have occurred? ______________________________

(NOTE: Discuss your results with the instructor.)

O. Turn off equipment

P. Clean work area and put away equipment and materials

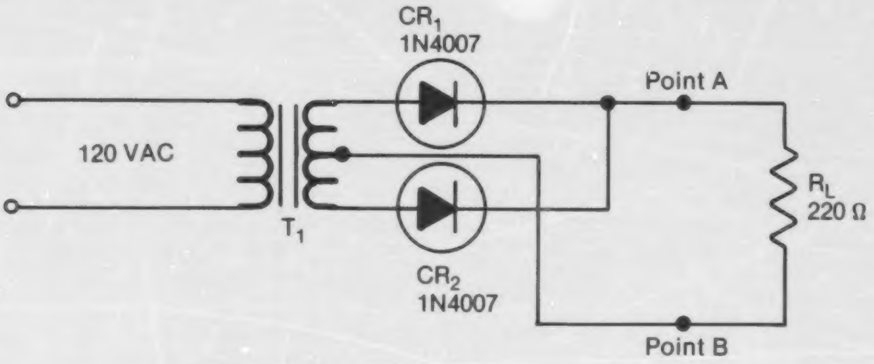
JOB SHEET #2

III. Procedure using a full-wave rectifier

A. Reassemble the circuit as shown in Figure 25, making the required connection

(NOTE: Have instructor check circuit before proceeding.)

FIGURE 25


CR$_1$
1N4007
Point A
120 VAC
R$_L$
220 Ω
T$_1$
CR$_2$
1N4007
Point B

B. Connect oscilloscope across load resistor if it has been disconnected

C. Measure peak voltage; record voltage and draw waveform in space provided below

Peak voltage = ____________________

D. Turn off power and connect 10-microfarad capacitor to points A and B shown in Figure 24

JOB SHEET #2

E. Turn on power; draw waveform in space provided below, recording all voltages

F. Calculate rms of ripple and record below

rms ripple = ______________________

G. Calculate E_{DC} and record below

E_{DC} = ______________________

H. Calculate percentage of ripple and record below

% of ripple = ______________________

JOB SHEET #2

I. Turn off power and replace 10-microfarad capacitor with 150-microfarad capacitor

J. Repeat steps E through H; record below

rms ripple = ____________________

E_{DC} = ____________________

% of ripple = ____________________

K. Turn off power and replace 150-microfarad capacitor with 300-microfarad capacitor

L. Again repeat steps E through H and record below

rms ripple = ____________________

E_{DC} = ____________________

% of ripple = ____________________

M. Which capacitor showed the best filtering? ____________________

N. With which circuit and filter was the best filtering or least amount of percent of ripple found?

____

Why? ____

____

____

(NOTE: Discuss your results with the instructor.)

O. Turn off equipment

P. Clean work area and put equipment and materials away

FILTERING CIRCUITS
UNIT III

JOB SHEET #3 — ANALYZE LC FILTER CIRCUITS

I. Equipment and materials

   A. Low power transformer, 120 VAC/12.6 volt center tap

   B. Two diodes, 1N4007 or equivalent

   C. Capacitor, 10 microfarad, 25 volt minimum

   D. Capacitor, 150 microfarad, 25 volt minimum

   E. Capacitor, 300 microfarad, 25 volt minimum

   F. Resistor, 330 ohm, 1 watt

   G. Inductor, 3.9 millihenry

   H. Inductor, 10 millihenry

   I. Oscilloscope

   J. Breadboard

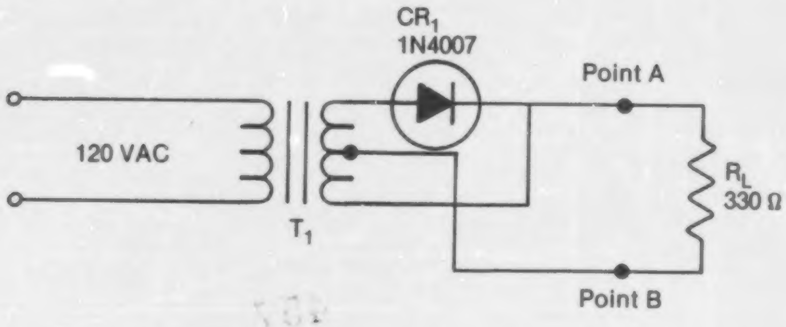
   K. Test leads

II. Procedure using half-wave rectifier

   A. Construct circuit as shown in Figure 26

   (NOTE: Have instructor check circuit before proceeding.)

FIGURE 26



JOB SHEET #3

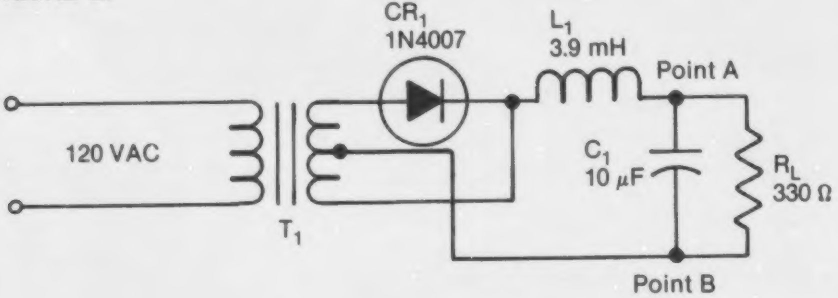
B. Connect oscilloscope across load resistor

C. Measure peak voltage; record voltage and draw waveform in space provided

Peak voltage = ____________________

D. Turn off power and connect 3.9-millihenry inductor and 10-microfarad capacitor at points A and B shown in Figure 27

FIGURE 27


CR$_1$
1N4007
L$_1$
3.9 mH
Point A
120 VAC
C$_1$
10 μF
R$_L$
330 Ω
T$_1$
Point B

E. Turn on power and draw the waveform in the space below, recording all voltages

JOB SHEET #3

F. Calculate rms of ripple and record

rms of ripple = ____________________

G. Calculate E_{DC} and record

E_{DC} = ____

H. Calculate percent of ripple and record

% of ripple = ____

I. Turn off power and replace 10-microfarad capacitor with 150-microfarad capacitor

JOB SHEET #3

J. Repeat steps E through H; record results and draw waveform in space provided below

rms ripple = ____________________

E_{DC} = ____________________

% of ripple = ____________________

K. Turn off power and replace 150-microfarad capacitor with 300-microfarad capacitor

L. Again repeat steps E through H; record results and draw waveform in space provided below

rms ripple = ____________________

E_{DC} = ____________________

% of ripple = ____________________

M. Turn off power, replace 3.9 millihenry inductor with 10 millihenry inductor, and replace 300 microfarad capacitor with 10 microfarad capacitor

JOB SHEET #3

N. Repeat steps E through H and record; draw waveform in space provided

rms ripple = ____________________

E_{DC} = ____________________

% of ripple = ____________________

O. Turn off power and replace the 10 microfarad capacitor with 150 microfarad capacitor

P. Repeat steps E through H and record; draw waveform in space provided

rms ripple = ____________________

E_{DC} = ____________________

% of ripple = ____________________

Q. Turn off power and replace the 150-microfarad capacitor with the 300-microfarad capacitor

JOB SHEET #3

R. Repeat steps E through H and record; draw waveform in space provided

rms ripple = ____________________

E_{DC} = ____________________

% of ripple = ____________________

S. Did the values of percentage of ripple improve with the larger inductor? ____________ With the larger capacitor? ________________________

(NOTE: Discuss your results with the instructor.)

T. Turn off equipment

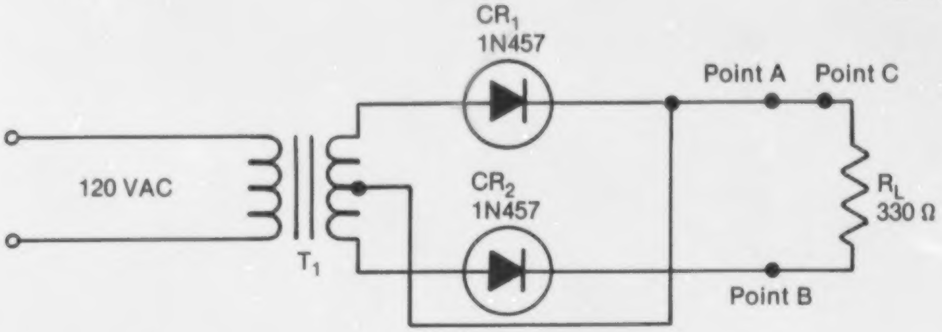
U. Clean work area and put away all equipment and materials

III. Procedure using a full-wave rectifier

A. Reassemble circuit as shown in Figure 28

(NOTE: Have instructor check circuit before proceeding.)

FIGURE 28


CR_1
1N457
Point A
Point C
120 VAC
CR_2
1N457
R_L
330 Ω
T_1
Point B

JOB SHEET #3

B. Connect oscilloscope across load resistor

C. Measure peak voltage and record; draw waveform in space provided below

Peak voltage = ____________________

D. Turn off power; remove jumper and insert 3.9-millihenry inductor between points A and C and 10-microfarad capacitor between points B and C indicated in Figure 28

E. Turn on power and draw waveform in space provided below, indicating all voltages

F. Calculate rms of ripple and record

rms ripple = ____

JOB SHEET #3

G. Calculate E_{DC} and record

E_{DC} = ______________________________

H. Calculate percent of ripple and record

% of ripple = ______________________________

I. Turn off power and replace 10-microfarad capacitor with 150-microfarad capacitor

J. Repeat steps E through H and record

rms ripple = ____________________

E_{DC} = ____________________

% of ripple = ____________________

JOB SHEET #3

K. Turn off power and replace 150-microfarad capacitor with 300-microfarad capacitor

L. Repeat steps E through H and record

rms ripple = ____________________

E_{DC} = ____________________

% of ripple = ____________________

M. Compare readings of the three capacitors with readings obtained with the half-wave rectifier

1. How do the readings compare? ____________________________
   ____
   ____
2. Why? ____
   ____

N. Turn off power; replace 3.9-millihenry inductor with 10-millihenry inductor, and replace 300-microfarad capacitor with the 10-microfarad capacitor

O. Repeat steps E through H and record

rms ripple = ____________________

E_{DC} = ____________________

% of ripple = ____________________

JOB SHEET #3

P. Turn off power and replace 10-microfarad capacitor with 150-microfarad capacitor

Q. Repeat steps E through H and record

rms ripple = ____________________

E_{DC} = ____________________

% of ripple = ____________________

R. Turn off power and replace 150-microfarad capacitor with 300-microfarad capacitor

S. Repeat steps E through H and record

rms ripple = ____________________

E_{DC} = ____________________

% of ripple = ____________________

T. Did the values of percentage of ripple improve with the larger inductor?

____

If so, why? ____

____

JOB SHEET #3

U. Of the circuits in Job Sheets #1 through #3, which combination of filters and circuits gave the best filtering?

____

____

(NOTE: Discuss your results with the instructor.)

V. Turn off equipment

W. Clean work area and put away all equipment and materials

FILTERING CIRCUITS
UNIT III

JOB SHEET #4 — ANALYZE A BAND-PASS FILTER

I. Equipment and materials

   A. Multimeter

   B. Function generator

   C. Capacitor, 0.033 microfarad

   D. Capacitor, 0.27 microfarad

   E. Inductor, 3.9 millihenry

   F. Inductor, 0.5 millihenry

   G. Resistor, 120 ohm, 1 watt

   H. Breadboard

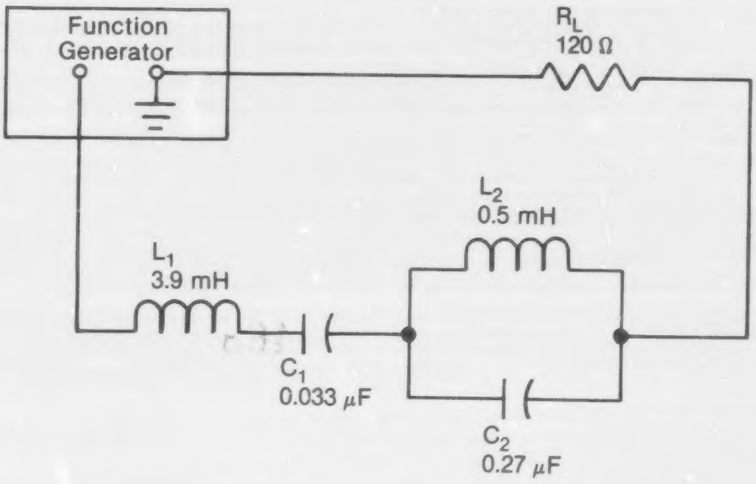
   I. Test leads

II. Procedure

   A. Construct circuit as shown in Figure 29

      (NOTE: Have instructor check circuit before proceeding.)

FIGURE 29


Function Generator
R_L 120 Ω
L_2 0.5 mH
L_1 3.9 mH
C_1 0.033 μF
C_2 0.27 μF

JOB SHEET #4

B. Hook multimeter across load resistor

C. Turn function generator to 10-kilohertz multiplier range with frequency adjusted fully clockwise

D. Turn on function generator; adjust amplitude to 15-volts rms

E. Slowly turn frequency range counterclockwise while watching multimeter

F. Record frequency reading

Frequency = ____________________

(NOTE: Voltage should be zero until f_{c_1} is reached, then voltage will increase.)

G. Continue turning frequency adjustment until the amplitude decreases to minimum; record reading

(NOTE: This frequency should be f_{c_2}.)

Frequency = ____________________

H. Do the readings in steps F and G compare with the information from Assignment Sheet #1? ____

(NOTE: Discuss your results with the instructor.)

I. Turn off equipment

J. Clean work area and put away all equipment and materials

FILTERING CIRCUITS
UNIT III

TEST

NAME ______________________________ SCORE ______________

1. Match terms associated with filtering circuits to their correct definitions. Write the correct numbers in the blanks.

_____a. Undesirable low-frequency pulsating component of DC power

_____b. Unit of frequency equal to one cycle per second

_____c. Components that change impedance characteristics in response to frequency changes

_____d. Range of frequencies

_____e. Integer multiple of a frequency

_____f. Circuit that reacts to alternating electromagnetic waveforms and reduces or separates certain frequencies

_____g. High-frequency transmitted electromagnetic waves generated by transmitters, lightning, and electrical equipment

_____h. Frequency at which a circuit's reactive components are equal

_____i. Combined effects to AC of resistance, capacitive reactance, and inductive reactance

_____j. Ability of a circuit or electronic device to withstand external interference radio waves

_____k. Filter circuit containing active components such as diodes and transistors

_____l. High-frequency interference

_____m. Opposition to AC resulting from capacitance or inductance

_____n. Measure of a circuit's or instrument's effectiveness in transmitting different frequencies applied to it

_____o. Filter circuit containing only passive components such as resistors, capacitors, and inductors

1. Filter
2. Radio waves
3. Active filter
4. Ripple
5. Noise
6. Harmonic
7. Reactance
8. Hertz
9. Impedance
10. Resonant frequency
11. Reactive components
12. Radio frequency integrity
13. Passive filter
14. Band
15. Frequency response

TEST

2. Match abbreviations associated with filtering circuits to their correct interpretations. Write the correct numbers in the blanks.

______a. Farad

______b. Henry

______c. Resistive/capacitive circuit

______d. Impedance

______e. Electromagnetic interference

______f. Bandwidth

______g. Microfarads

______h. Channel

______i. Frequency cutoff or cutoff frequency

______j. Radio frequency interference; radio frequency integrity

______k. Quality (of a filter or component)

______l. Peak to peak

______m. Common-mode rejection

______n. Federal Aviation Administration

______o. Inductive reactance

______p. Frequency

______q. Inductive/capacitive circuit

______r. Capacitive reactance

______s. Resistance

______t. Federal Communications Commission

______u. Average voltage

______v. Inductance

______w. Capacitance

______x. Resonant frequency

______y. Picofarad

______z. Direct current voltage

______aa. Hertz

______bb. Root mean square

______cc. Filter

______dd. Steady direct current

1. RFI
2. FAA
3. pk-pk
4. CMR
5. Z
6. emi
7. RC
8. F
9. X_L
10. f_c
11. Hz
12. CH
13. H
14. Q
15. MF or μF
16. Freq or f
17. LC
18. R
19. f_r
20. X_C
21. VDC
22. E_{DC}
23. Bw
24. pF
25. L
26. E_{ave}
27. C
28. rms
29. FI
30. FCC

TEST

3. Match symbols associated with filtering circuits to their correct interpretations. Write the correct numbers in the blanks.

______a. Square root

______b. Wave trap (as shown on power transmission one-line diagrams)

______c. Greater than

______d. Infinite (extremely large)

______e. Greek letter pi; mathematical constant equal to approximately 3.1416

______f. Less than

______g. Fixed resistor

______h. Variable resistor (potentiometer)

______i. Capacitor

______j. Variable capacitor (trimmer)

______k. Feedthrough capacitor

______l. Air core inductor (choke)

______m. Iron core inductor

______n. Saturable core inductor

______o. Variable core inductor (tuning slug)

______p. Probe

______q. Operational amplifier

______r. Iron core transformer

______s. Air core transformer

______t. Saturable core transformer

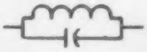
______u. Zener diode

______v. Thyrector

1. >

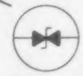
2. ∞

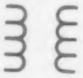
3. π

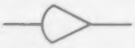
4. 

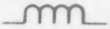
5. √

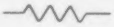
6. <

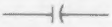
7. 

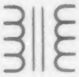
8. 

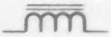
9. 

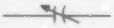
10. 

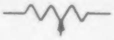
11. 

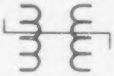
12. 

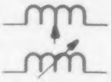
13. 

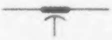
14. 

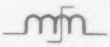
15. 

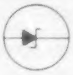
16. 

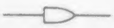
17. 

18. 

19. 

20. 

21. 

22. 

TEST

4. State the primary applications of filters.

a. ____________________

b. ____________________

c. ____________________

5. Label prefixes with their correct powers of ten. Write the correct values in the blanks.

a. μ (micro) = ____________

b. M (mega) = ____________

c. T (tera) = ____________

d. p (pico) = ____________

e. k (kilo) = ____________

f. m (milli) = ____________

g. G (giga) = ____________

h. n (nano) = ____________

6. Match frequency bands to their correct ranges. Write the correct numbers in the blanks.

_____a. 300 MHz to 3 GHz

_____b. 300 kHz to 3 MHz

_____c. Below 30 kHz

_____d. 30 GHz to 300 GHz

_____e. 30 kHz to 300 kHz

_____f. 3 MHz to 30 MHz

_____g. 3 GHz to 30 GHz

_____h. 30 MHz to 300 MHz

1. VLF (very low frequency)
2. LF (low frequency)
3. MF (medium frequency)
4. HF (high frequency)
5. VHF (very high frequency)
6. UHF (ultra-high frequency)
7. SHF (super high frequency)
8. EHF (extremely high frequency)

TEST

7. Match filter circuit components to their correct functions. Write the correct numbers in the blanks.

_____a. Passes high frequencies with less impedance than low frequencies

_____b. Passes low frequencies with less impedance than high frequencies

_____c. Often used to isolate and filter, usually in conjunction with capacitors

_____d. Passes all frequencies with the same impedance

_____e. Utilizes feedback to perform low-frequency filtering without inductors

_____f. Used to filter high-voltage transients of one polarity

_____g. Used to filter high-voltage transients of either polarity

1. Thyrector
2. Operational amplifier
3. Resistor
4. Zener diode
5. Capacitor
6. Transformer
7. Inductor (choke)

8. Describe filters classified according to their functions.

a. Low-pass — ____

____

b. High-pass — ____

____

c. Band-pass — ____

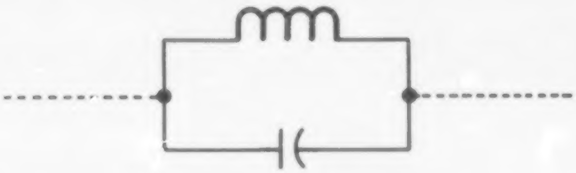
____

d. Band-reject — ____

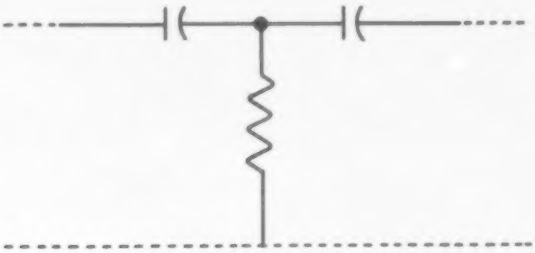
____

TEST

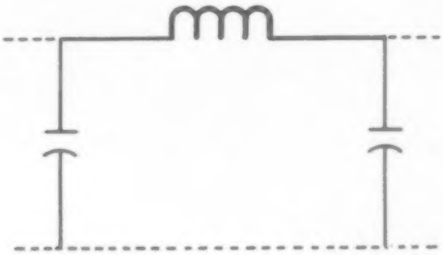
9. Label the following filter configurations. Write the correct names in the blanks.



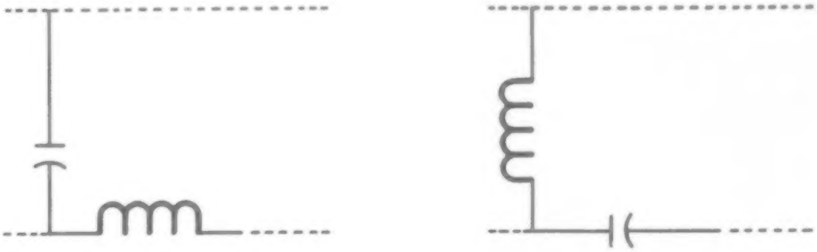
a. ____



b. ____



c. ____



d. ____

TEST

10. Distinguish among component oppositions to power transfer. Write an "R" in the blanks before resistor restrictions, a "C" before capacitor restrictions, and an "L" in the blanks before inductor restrictions.

_____a. AC opposition decreases as frequency increases

_____b. DC opposition is equal to resistance

_____c. DC opposition is infinite

_____d. AC opposition is equal to resistance

_____e. AC opposition increases as frequency increases

_____f. DC opposition is equal to conductor resistance and is very low

11. Calculate reactance for the problems given below. Use the formulas $X_C = \frac{1}{2\pi fC}$ and $X_L = 2\pi fL$. Show your work.

a. Calculate the capacitive reactance for a 40-microfarad capacitor operating at 2 kilohertz.

X_C = ____________________

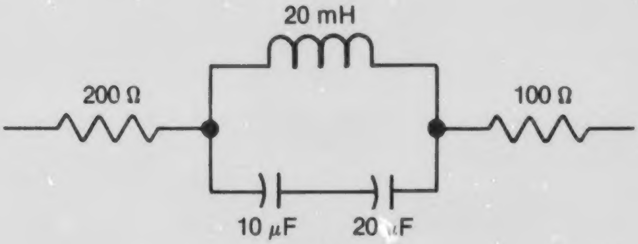
b. Calculate the inductive reactance for a 50-millihenry choke operating at 4 kilohertz.

X_L = ____________________

TEST

12. Calculate impedance for the circuit shown below if it is operating at 3 kilohertz. Use the correct formula $Z = \frac{X_L \times X_C}{X_L - X_C} + R$.

Z = ____________________



13. Calculate resonant frequency for an 80-microfarad capacitor in series with an 18-millihenry inductor. Use the formula $f_r = \frac{1}{2\pi\sqrt{LC}}$. Show your work.

f_r = ____________________

TEST

14. Calculate the percentage of ripple for a 40-volt zero-to-peak power source with a peak-to-peak ripple of 6 volts. Use the formula $\% \text{ ripple} = \frac{\text{rms ripple}}{E_{ave}} \times 100$. Show your work.

% ripple = ____________________

15. Calculate the component values required for a low-pass filter with a 1000-ohm input resistance and a cutoff frequency of 4 kilohertz. Use the following formulas for a π filter: $L = \frac{R}{\pi f_c}$ and $C = \frac{1}{2 \pi f_c R}$. Show your work.

L = ____________________

C = ____________________

16. List sources of electrical noise.

a. ____

b. ____

c. ____

TEST

d. ____________________

e. ____________________

(NOTE: Test questions 17 and 18 list the assignment and job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

17. Determine filter effects on various frequency bands.

18. Demonstrate the ability to

    a. Analyze various LC filters.

    b. Analyze capacitive filter circuits.

    c. Analyze LC filter circuits.

    d. Analyze a band-pass filter.

FILTERING CIRCUITS
UNIT III

ANSWERS TO TEST

1.	a.	4	f.	1	k.	3
	b.	8	g.	2	l.	5
	c.	11	h.	10	m.	7
	d.	14	i.	9	n.	15
	e.	6	j.	12	o.	13

2.	a.	8	i.	10	q.	17	y.	24
	b.	13	j.	1	r.	20	z.	22
	c.	7	k.	14	s.	18	aa.	11
	d.	5	l.	3	t.	30	bb.	28
	e.	6	m.	4	u.	26	cc.	29
	f.	23	n.	2	v.	25	dd.	21
	g.	15	o.	9	w.	27		
	h.	12	p.	16	x.	19		

3.	a.	5	g.	11	m.	14	s.	8
	b.	4	h.	16	n.	20	t.	17
	c.	1	i.	12	o.	18	u.	21
	d.	2	j.	15	p.	22	v.	7
	e.	3	k.	19	q.	9		
	f.	6	l.	10	r.	13		

ANSWERS TO TEST

4. a. Removing pulsations and transients from DC

   b. Shaping waveforms

   c. Separating frequencies

5. a. 10^{-6} e. 10^{3}

   b. 10^{6} f. 10^{-3}

   c. 10^{12} g. 10^{9}

   d. 10^{-12} h. 10^{-9}

6. a. 6 e. 2

   b. 3 f. 4

   c. 1 g. 7

   d. 8 h. 5

7. a. 5 e. 2

   b. 7 f. 4

   c. 6 g. 1

   d. 3

8. Description should include the following

   a. Low-pass — Passes lower range of frequencies and impedes higher range

   b. High-pass — Passes higher range of frequencies and impedes lower range

   c. Band-pass — Passes a band of frequencies and impedes those frequencies above and below that range

   d. Band-reject — Passes all frequencies except a range that is impeded

9. a. Band-reject type c. π type

   b. T type d. L type

ANSWERS TO TEST

10. a. C
    b. R
    c. C
    d. R
    e. L
    f. L

11. a. $1.99\ \Omega$
    b. $1{,}256\ \Omega$

12. $308.1\ \Omega$

13. 132.7 Hz

14. % ripple = 5.7

    (NOTE: $E_{ave} = 37$ V and rms ripple = 2.12 V.)

15. $L = 79.6$ mH

    $C = 0.04\ \mu F$

16. a. Poor power supply filtering
    b. Natural sources
    c. Electrical equipment
    d. Defective equipment
    e. Improperly maintained equipment

17. Evaluated to the satisfaction of the instructor

18. Performance skills evaluated to the satisfaction of the instructor

BASIC OSCILLATOR AND MULTIVIBRATOR CIRCUITS
UNIT IV

UNIT OBJECTIVE

After completing this unit, the student should be able to recognize basic oscillator and multivibrator circuits, and be able to construct and tune these circuits. The student will show this knowledge by completing job sheets and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match to their correct definitions terms associated with oscillators and multivibrators.
2. Match to their correct interpretations abbreviations associated with oscillators and multivibrators.
3. Identify oscillator circuit diagrams.
4. State the frequency-determining components and the feedback paths of various oscillators.
5. Match types of multivibrators to their correct descriptions.
6. Identify multivibrator circuit diagrams.
7. Identify multivibrator logic and block-diagram symbols.
8. Match input and output descriptions to correct types of multivibrator.
9. Demonstrate the ability to
    a. Analyze a tuned-collector tuned-base oscillator.
    b. Analyze a crystal oscillator.
    c. Analyze an astable multivibrator.

BASIC OSCILLATOR AND MULTIVIBRATOR CIRCUITS
UNIT IV

SUGGESTED ACTIVITIES

I. Suggested activities

   A. Make transparencies.

   B. Gather equipment and materials for job sheet demonstrations.

   C. Provide students with objective sheet.

   D. Discuss unit and specific objectives. State need for knowledge in each area.

   E. Provide students with information and job sheets.

   F. Discuss information sheet.

   G. Construct a monostable multivibrator. Connect it to a signal generator at the input and an oscilloscope at the output. Show the RC time-constant effect on the pulse width as the potentiometer is changed.

   H. Construct various oscillators; demonstrate the effects of tuning the tank circuits or varying capacitors.

   I. Demonstrate and discuss procedures outlined in the job sheets.

   J. Give test.

   K. Reteach and retest if necessary.

II. Instructional materials

   A. Objective sheet

   B. Suggested activities

   C. Information sheet

   D. Transparency masters

      1. TM #1 — Armstrong Oscillator

      2. TM #2 — Tuned-Collector Tuned-Base Oscillator

      3. TM #3 — Hartley Oscillator

      4. TM #4 — Colpitts Oscillator

SUGGESTED ACTIVITIES

5. TM #5 — Crystal Oscillator
6. TM #6 — Push/Pull Oscillator
7. TM #7 — RC Phase-Shift Oscillator
8. TM #8 — Astable Multivibrator
9. TM #9 — Monostable Multivibrator
10. TM #10 — Bistable Multivibrator

E. Job sheets

1. Job Sheet #1 — Analyze a Tuned-Collector Tuned-Base Oscillator
2. Job Sheet #2 — Analyze a Crystal Oscillator
3. Job Sheet #3 — Analyze an Astable Multivibrator

F. Test

G. Answers to test

III. Unit references

A. Grob, Bernard, and Milton S. Kiver. *Applications of Electronics,* 2nd ed. New York: McGraw-Hill Book Company, 1966.

B. McDonald, Lorne. *Practical Analysis of Electronic Circuits Through Experimentation.* Seal Beach, California: The Technical Education Press, 1978.

C. *Oscillators and Multivibrators: Understanding, Maintaining, and Troubleshooting Oscillator and Multivibrator Circuits.* Barrington, Illinois: TPC Training Systems, Division of Technical Publishing Company, 1978.

D. Shrader, Robert L. *Electronic Communication,* 3rd ed. New York: McGraw-Hill Book Company, 1980.

E. Shrader, Robert L. *Electronic Fundamentals for Technicians.* New York: McGraw-Hill Book Company, 1972.

BASIC OSCILLATOR AND MULTIVIBRATOR CIRCUITS
UNIT IV

INFORMATION SHEET

I. Terms and definitions

A. Oscillator — Amplifier with controlled feedback that produces an alternating output signal

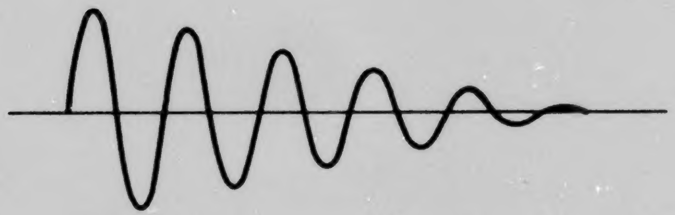
(NOTE: Virtually any high-gain amplifier circuit is capable of producing oscillations if a feedback path exists from the output to the input with the correct phase relationship. Oscillations often occur as undesirable symptoms of defective circuits. The high pitch that results when microphone amplifiers are adjusted for high gain and the speaker output feeds back into the microphone is an example of oscillation due to high gain and feedback. This is a frequent occurrence at meetings and concerts where amplifiers and microphones are used.)

B. Oscillation — Uniformly alternating output

C. Damping — Reduction of oscillation amplitude (Figure 1)

EXAMPLE: Damped oscillation

FIGURE 1



D. Feedback — Method of connecting a fraction of an output signal back to input of circuit

E. Negative feedback (degenerative) — Feedback that reduces output by supplying an opposing voltage back to input of circuit

(NOTE: Negative feedback increases stability.)

F. Positive feedback (regenerative) — Feedback that reinforces output by supplying a boosting voltage back to input of circuit

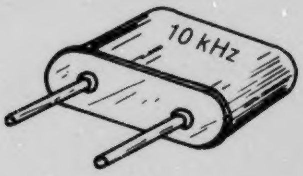
(NOTE: Extreme positive feedback to any amplifier will result in oscillation or circuit overloads. Feedback is used to produce oscillations where desired, or to inhibit oscillation in circuits where it is not desirable. Feedback is common in linear control circuits to obtain the proper damping effects.)

INFORMATION SHEET

G. Crystal — Electronic component composed of crystalline substance, such as quartz, which is cut and shaped to produce a specific frequency of oscillation when electrically excited (Figure 2)

EXAMPLE:

FIGURE 2



Typical Radio-Frequency
Crystal (Encased)

H. Decade [illegible] — Assembly of resistors, capacitors, or coils; assembly contains two or more sections divided into ten equal parts, each section having ten times the value of the preceding section; by means of a ten-position selector switch, the assembly can be set to any desired value in its range

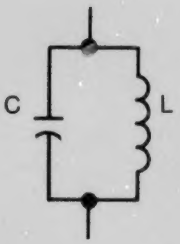
I. Bypass capacitor — Capacitor used to provide a comparatively low impedance path around a component (Transparency #1, C1)

(NOTE: In a common-emitter amplifier, a capacitor parallel to the emitter resistor is called a *swamping capacitor.* Used in a coupling between amplifier stages, a bypass capacitor may be referred to as a *speed-up capacitor.* C3 and C4 of the flip-flop in Transparency #10 square the wave form by providing rapid switching and are called *commuting capacitors.*)

J. Tank circuit — Circuit composed of an inductor and a capacitor in parallel used as a filtering circuit, a wave trap, a coupling circuit, or an oscillator frequency-determining circuit (Figure 3)

EXAMPLE:

FIGURE 3



INFORMATION SHEET

K. Resonant frequency — Frequency at which a circuit tends to vibrate or oscillate because of the capacitance and inductance combination

L. RC time constant — Time required for a capacitor to charge 63 percent of the voltage across it; equal to resistance times capacitance

M. Switching — Making, breaking, or changing the connections in an electrical circuit

(NOTE: Switching devices and programs are used in computers to make selections. When combined, computer switching circuits can perform logic operations. Switching is performed automatically upon receipt of specific signals.)

II. Abbreviations associated with oscillators and multivibrators and their interpretations

A. rf — Radio frequency

B. HF — High frequency

C. Hz — Hertz

D. kHz — Kilohertz

E. MHz — Megahertz

F. GHz — Gigahertz

G. af — Audio frequency, sonic frequency, sound frequency

H. XTL — Crystal

I. FF — Flip-flop

J. SS — Single shot

K. Osc — Oscillator

L. TP — Test point

M. MC — Master clock

N. VCO — Voltage-controlled oscillator

O. VFO — Variable-frequency oscillator

P. BFO — Beat-frequency oscillator

Q. RC — Resistive/capacitive circuit

R. LC — Inductive/capacitive circuit

INFORMATION SHEET

S. V_{CC} — Collector supply voltage

T. V_{BB} — Base supply voltage

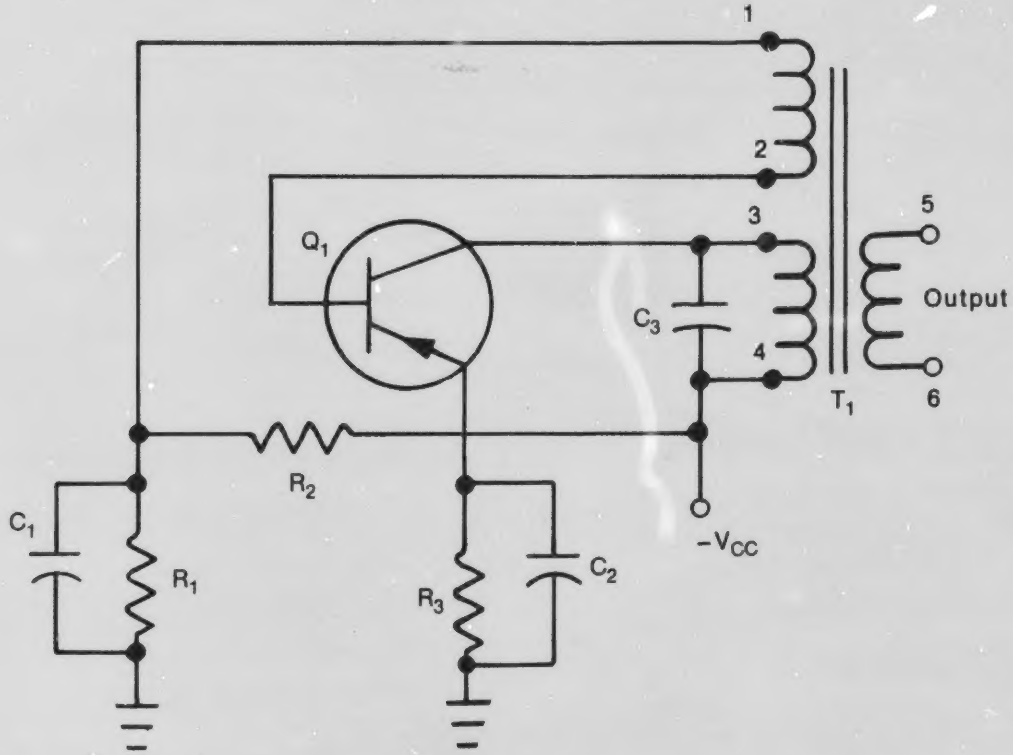
U. C_{cb} — Collector-base interterminal capacitance

III. Oscillator circuit diagrams (Figures 4-10)

A. Armstrong

(NOTE: The feedback circuit is the top transformer winding. It has the appearance of an arm reaching out. This should help you to recognize this circuit as the Armstrong oscillator. This circuit, or variations of it, is sometimes called a *tickler-coil oscillator.*)

FIGURE 4

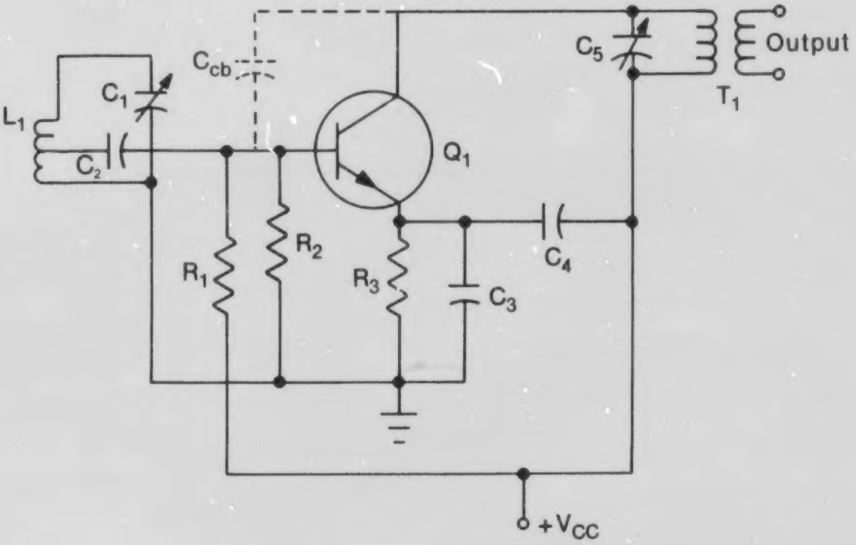


INFORMATION SHEET

B. Tuned-collector tuned-base

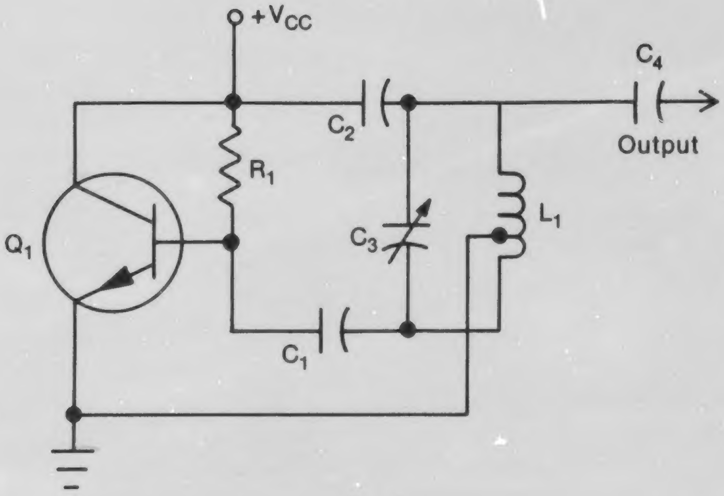
(NOTE: The base and collector circuits both contain tuned tank circuits; thus the oscillator is easily identified.)

FIGURE 5


C_{cb}
C_1
L_1
C_2
C_5
Output
T_1
Q_1
R_1
R_2
R_3
C_3
C_4
$+V_{CC}$

C. Hartley

FIGURE 6

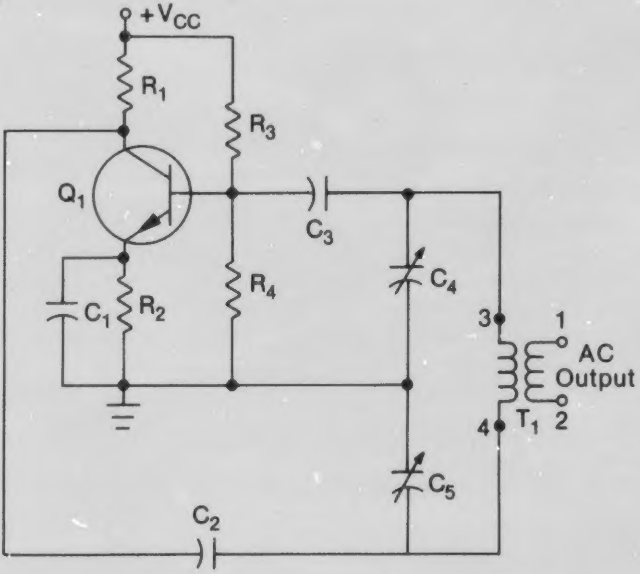

$+V_{CC}$
C_4
C_2
Output
R_1
L_1
Q_1
C_3
C_1

INFORMATION SHEET

D. Colpitts

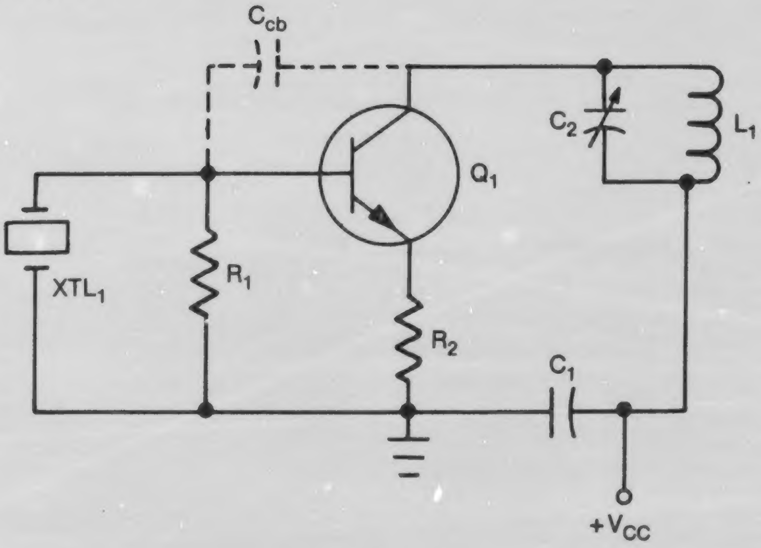
(NOTE: The Colpitts oscillator has two capacitors in the tank circuit, which are split by the connection made between them. This circuit is identified easily by remembering the phrase, "Capacitors split is a Colpitts.")

FIGURE 7


+VCC
R1
R3
Q1
C3
C4
R4
C1
R2
3
1
AC
Output
T1
4
2
C5
C2

E. Crystal

FIGURE 8

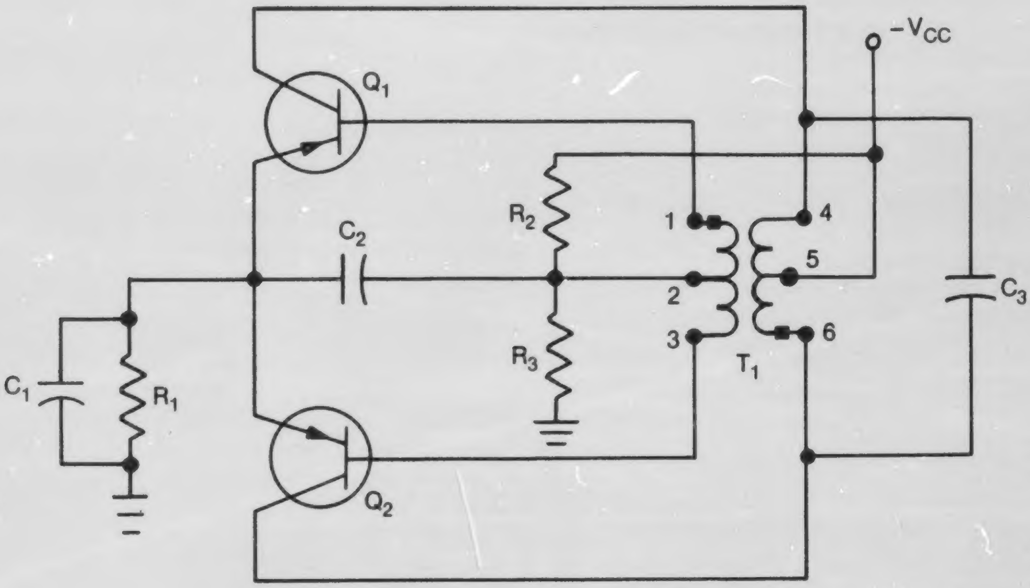

Ccb
C2
L1
Q1
XTL1
R1
R2
C1
+VCC

INFORMATION SHEET

F. Push/pull

(NOTE: The squares on the transformer indicate that polarity is opposite at points 1 and 4. Also, notice the swamping capacitor, C1.)

FIGURE 9

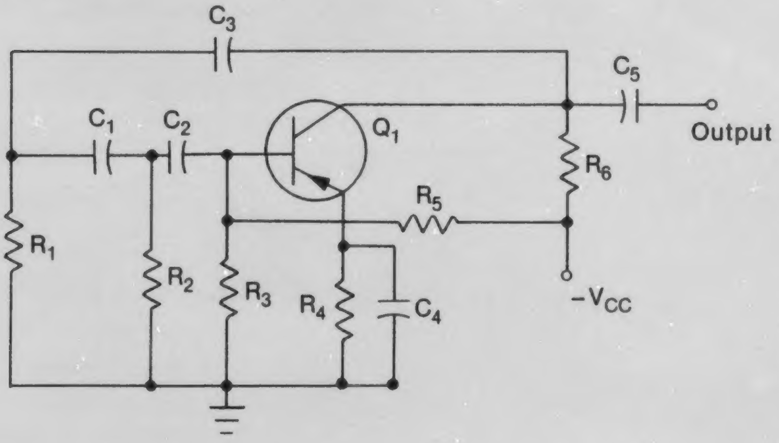

Q_1
$-V_{CC}$
R_2
C_2
1
4
5
2
C_3
3
6
R_3
T_1
C_1
R_1
Q_2

INFORMATION SHEET

G. RC phase shift

(NOTE: Notice the obvious feedback path through C1. This oscillator obtains a 180-degree phase shift: the sum of the three sets of capacitor/resistor couples [C1 and R1 through C3 and R3] each with a 60-degree phase shift. See Figure 10)

FIGURE 10



IV. Frequency-determining components and feedback paths of various oscillators

A. Armstrong (Transparency #1)

1. Frequency — C3 and T1 (terminals 3 and 4) resonant frequency
2. Feedback — T1 (terminals 1 and 2) to Q1 base

B. Tuned-collector tuned-base (Transparency #2)

1. Frequency — C1 and L1 resonant frequency matched to C5 and L2
2. Feedback — Q1 collector to base capacitance (C_{cb})

C. Hartley (Transparency #3)

1. Frequency — C2 and L1 resonant frequency
2. Feedback — C3 to base of Q1

D. Colpitts (Transparency #4)

1. Frequency — C1, C2, and T1 (terminals 3 and 4) resonant frequency
2. Feedback — C3 to base of Q1

INFORMATION SHEET

E. Crystal (Transparency #5)

   1. Frequency — XTL1 harmonic

      (NOTE: C1 and L1 must be tuned to the frequency of the crystal or to a harmonic of it.)

   2. Feedback — Q1 collector to base capacitance (C_{cb})

      (NOTE: The crystal oscillator is similar to the tuned-collector tuned-base oscillator. The tank circuit of the base has been replaced by the crystal.)

F. Push/pull (Transparency #6)

   1. Frequency — C2 and T1 (terminals 4 and 6) resonant frequency

   2. Feedback — T1 (terminals 1, 2, and 3) to Q1 and Q2 bases

G. RC phase shift (Transparency #7)

   1. Frequency — RC time constant of C1 and R1 through C3 and R3

   2. Feedback — C1, C2, C3 to base of Q1

V. Descriptions of various types of multivibrators

   A. Astable — Circuit that continually alternates between two unstable states at a frequency determined by the circuit components

      (NOTE: The astable multivibrator produces square waves and is also called a *free-running multivibrator.*)

   B. Monostable — Circuit having only one stable state from which it can be triggered to change; after a predetermined time, it returns to its original state

      (NOTE: A monostable multivibrator is also called a *one-shot, single-shot,* or *start/stop multivibrator.*)

   C. Bistable — Circuit having two stable states that will stay in either state until triggered to switch to the opposite state

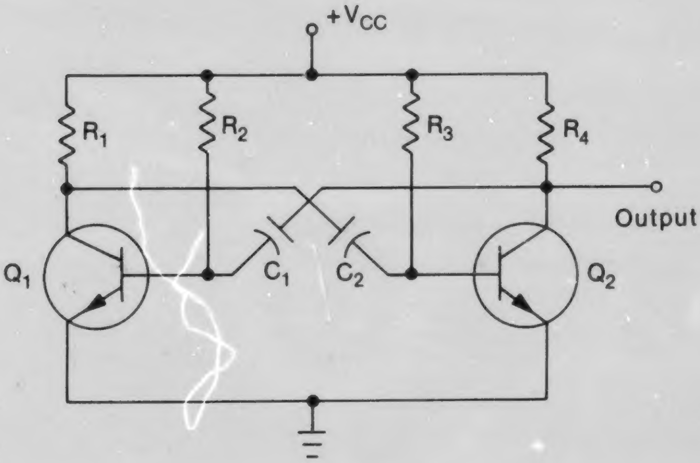
      (NOTE: The bistable multivibrator is also called a *flip-flop.*)

INFORMATION SHEET

VI. Multivibrator circuit diagrams (Figures 11-13)

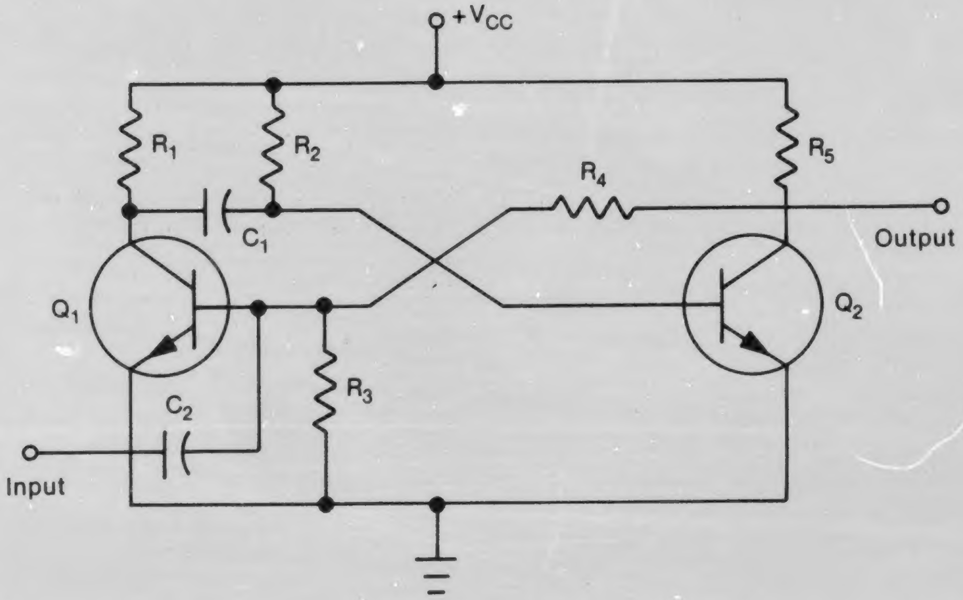
A. Astable

FIGURE 11


+V$_{CC}$
R$_1$
R$_2$
R$_3$
R$_4$
Output
Q$_1$
C$_1$
C$_2$
Q$_2$

B. Monostable

FIGURE 12

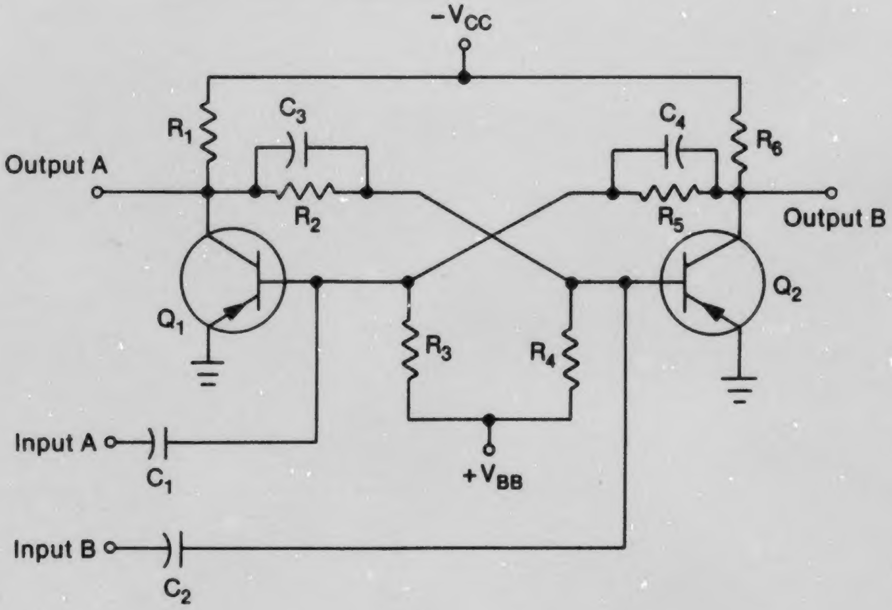

+V$_{CC}$
R$_1$
R$_2$
R$_5$
R$_4$
C$_1$
Output
Q$_1$
Q$_2$
R$_3$
C$_2$
Input

INFORMATION SHEET

C. **Bistable**

(NOTE: A third input called a *toggle input* may be added. Toggle input changes the state of the bistable multivibrator regardless of which state it is in.)

FIGURE 13


$-V_{CC}$
C_3
C_4
R_1
R_6
Output A
R_2
R_5
Output B
Q_1
Q_2
R_3
R_4
Input A
C_1
$+V_{BB}$
Input B
C_2

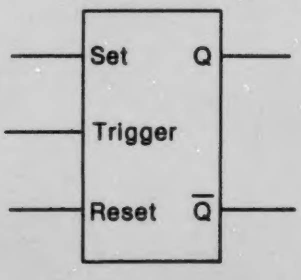
VII. Multivibrator logic and block-diagram symbols (Figures 14-17)

(NOTE: Various oscillators may be used in circuits. They are indicated by a block diagram according to their application. See Section III of the Information Sheet.)

A. **Bistable**

(NOTE: There are other types and variations of bistable multivibrators.)

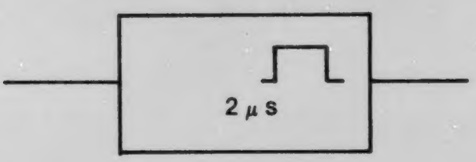
FIGURE 14


Set
Q
Trigger
Reset
$\overline{Q}$

INFORMATION SHEET

B. Monostable

FIGURE 15



C. Astable

FIGURE 16

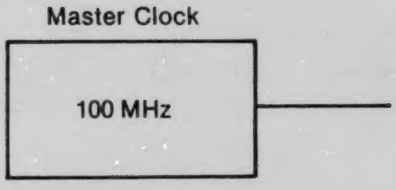
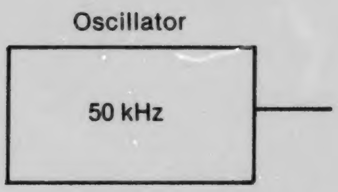

Master Clock
100 MHz

FIGURE 17


Oscillator
50 kHz

VIII. Multivibrator inputs and outputs (Figures 18-20)

A. Astable (Transparency #8)

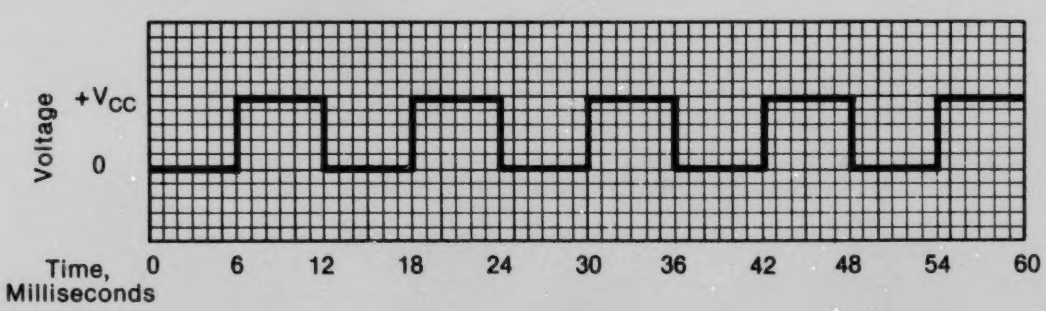
1. Input — None

INFORMATION SHEET

2. Output — Continuous, uniform square wave

EXAMPLE: Astable output

FIGURE 18



(NOTE: The square wave above would result from C1 and R2 being sized so that 5 RC time constants would equal approximately 6 milliseconds.)

B. Monostable (Transparency #9)

1. Input — Single input that can occur at random

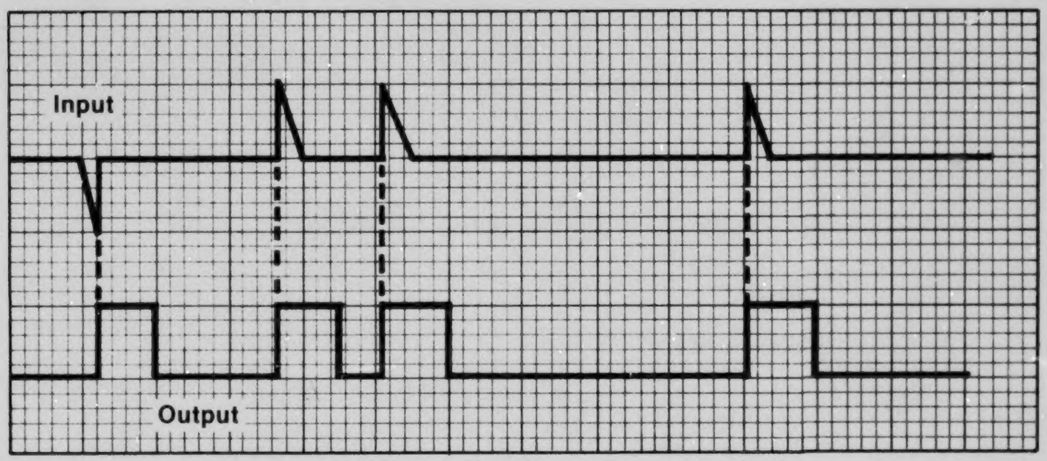
INFORMATION SHEET

2. Output — One rectangular pulse for each input positive transition

   (NOTE: The circuit responds to the positive transition because it is an npn transistor and is capacitively coupled to the input. The pulse width is determined by the values of R2 and C1. The frequency of the output depends on the frequency of the input.)

   EXAMPLE: Monostable input and output

FIGURE 19



C. Bistable (Transparency #10)

1. Inputs

   a. Set input — Forces one transistor on

   b. Reset input — Forces opposite transistor on

   c. Toggle input — Forces state to change

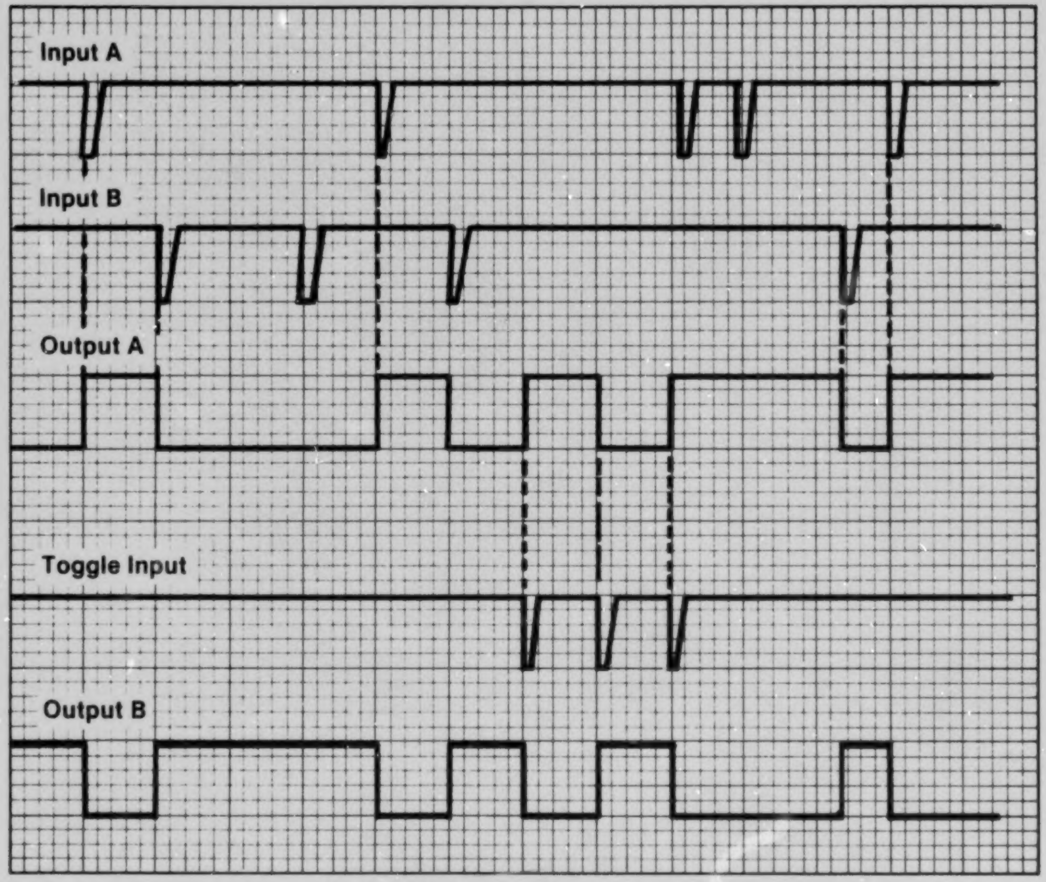
INFORMATION SHEET

2. Output — Usually two that are opposite

(NOTE: The bistable [flip-flop] could be constructed to function as a positive-logic circuit device or a negative-logic circuit device with the output-to-input relationship established accordingly.)

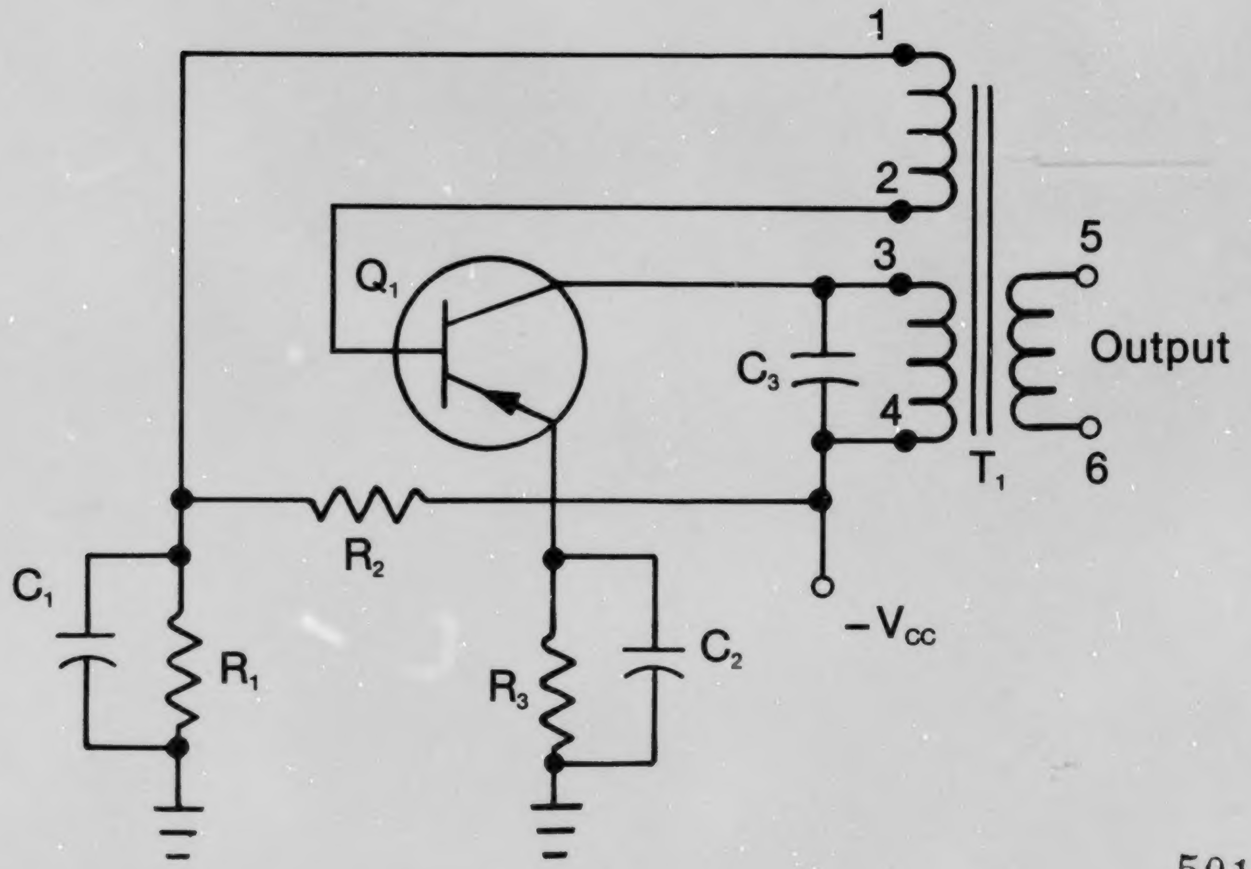
EXAMPLE: Bistable input and output

FIGURE 20

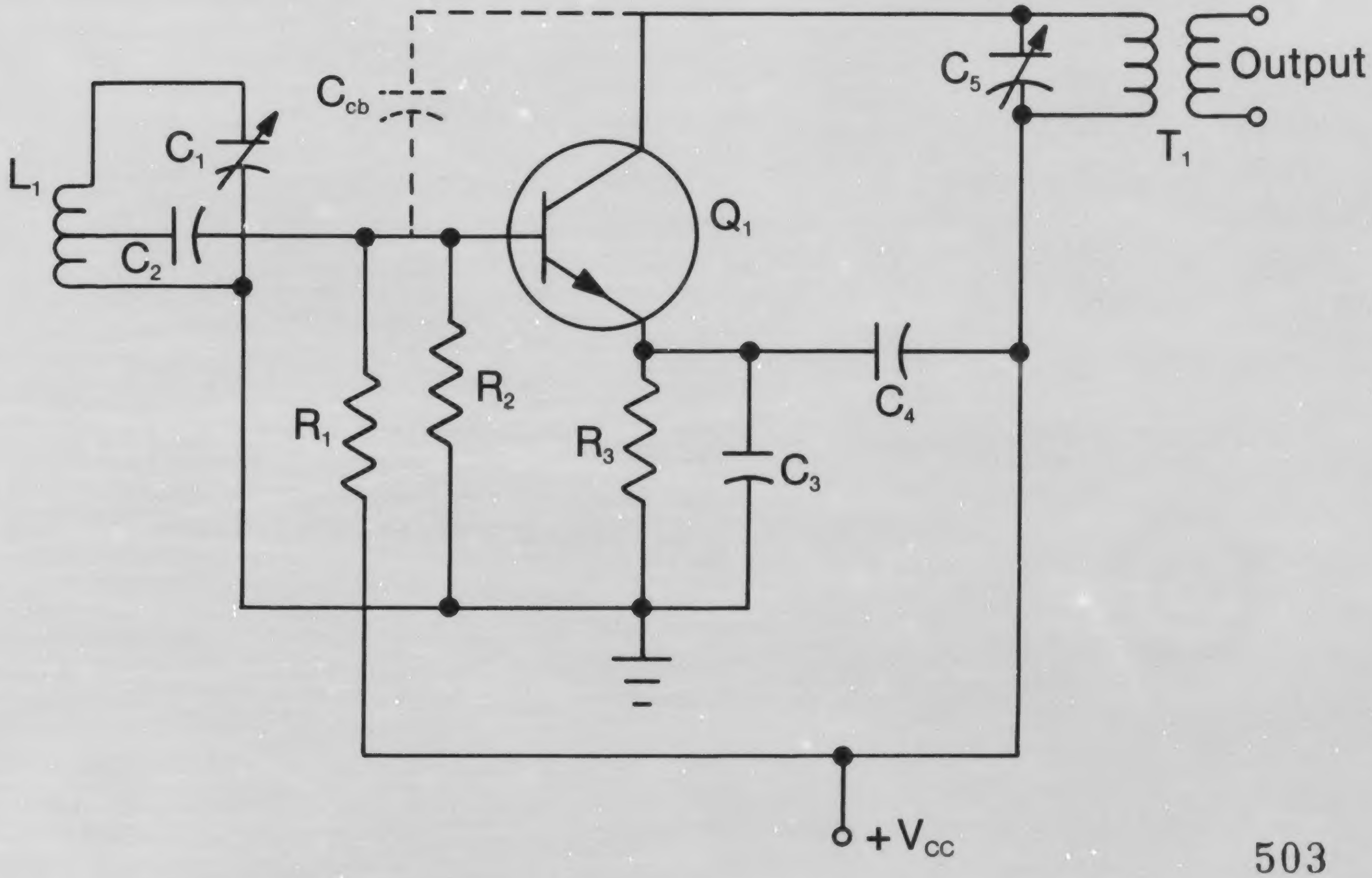


(NOTE: Output B is the exact opposite of Output A. Notice that Input A will make Output A go high if it is low at the time; but if it is already high, Output A has no effect. Input B will make Output A go low if it is high at the time; but if it is already low, Input B has no effect. Notice that the toggle input [not shown on Transparency #10] will change the state of the device regardless. A toggle input would usually be diode-connected to the point where $+V_{BB}$ is shown.)

Armstrong Oscillator


1
2
3
4
5
6
Q1
C3
T1
Output
R2
C1
R1
R3
C2
– Vcc

Tuned-Collector Tuned-Base Oscillator


L$_1$
C$_1$
C$_2$
C$_{cb}$
Q$_1$
R$_1$
R$_2$
R$_3$
C$_3$
C$_4$
C$_5$
T$_1$
Output
+V$_{CC}$

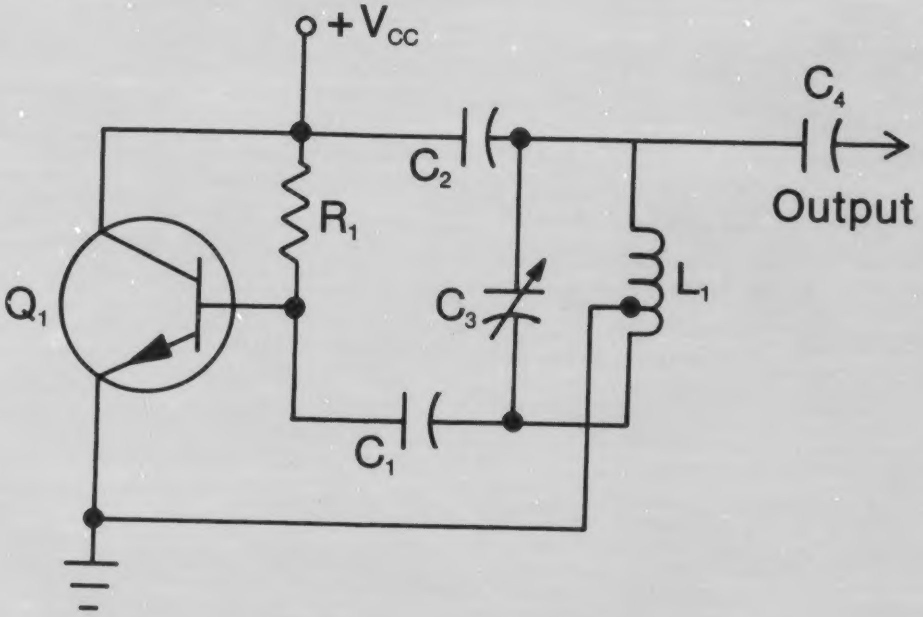
TM #2

502

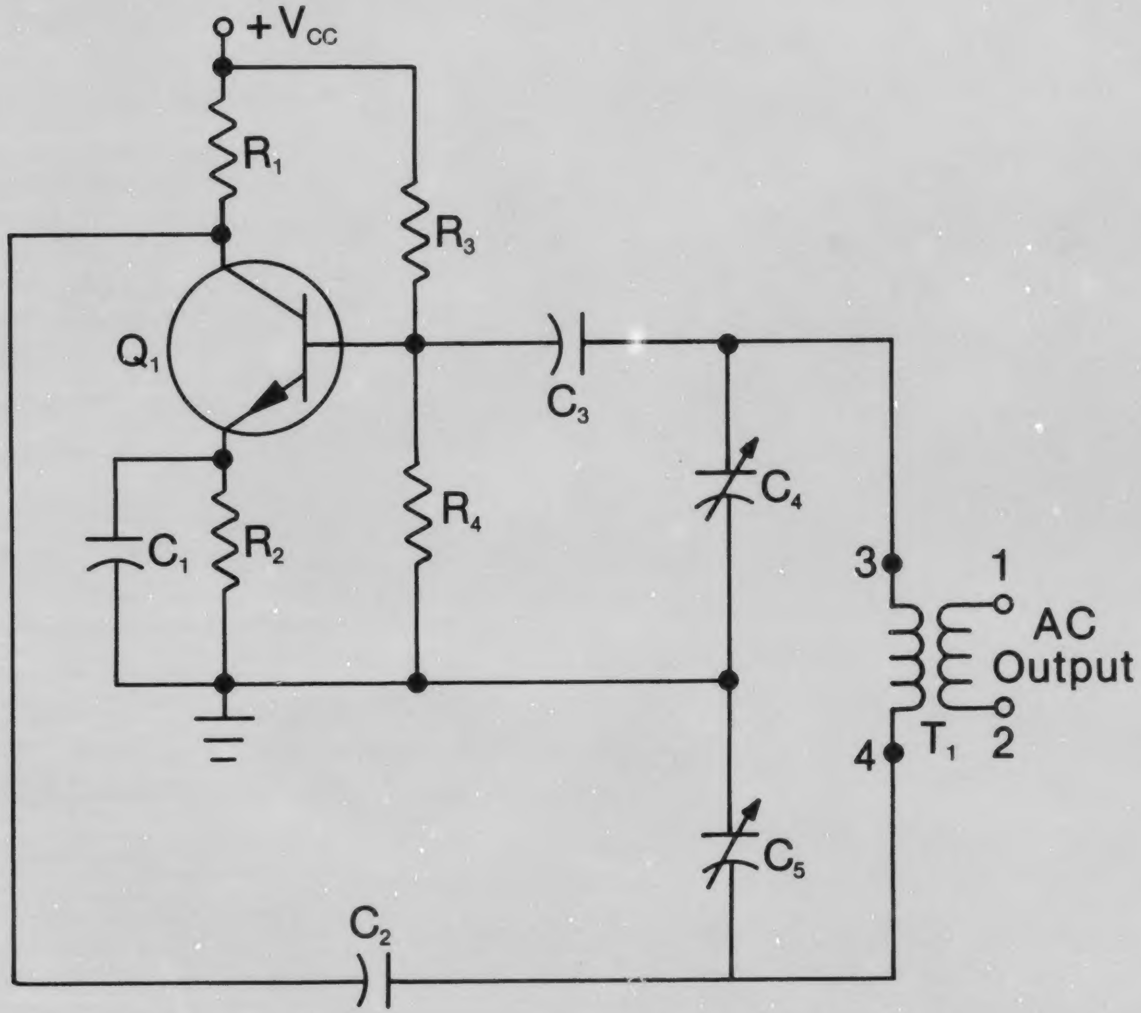
503

GIE - 281-B

Hartley Oscillator


+ V_{CC}
C_4
C_2
Output
R_1
L_1
Q_1
C_3
C_1

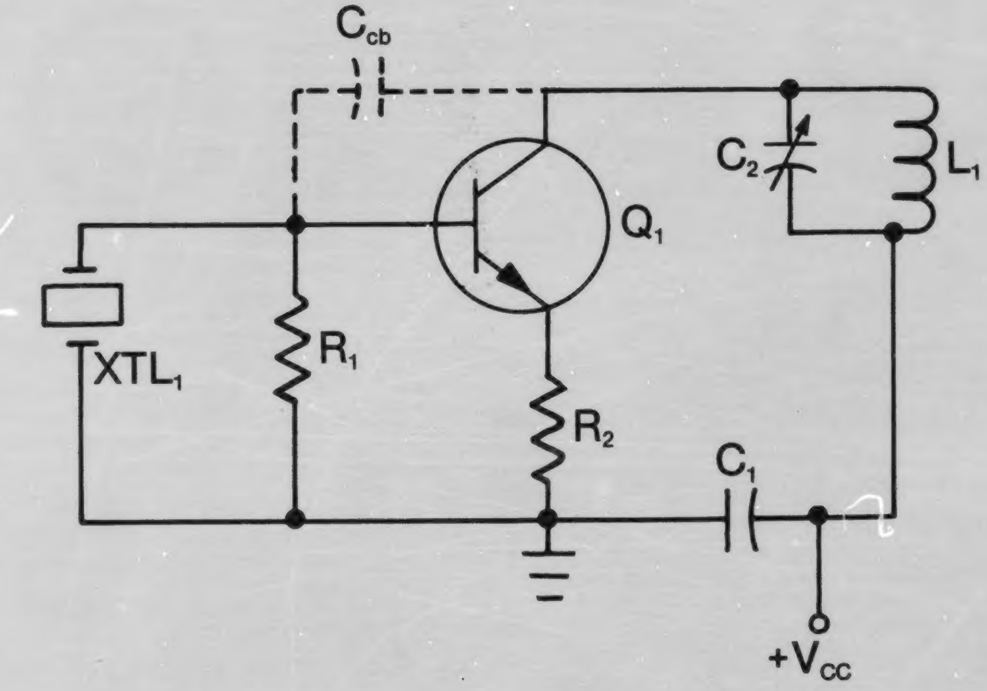
Colpitts Oscillator


+V$_{CC}$
R$_1$
R$_3$
Q$_1$
C$_3$
R$_4$
C$_4$
C$_1$
R$_2$
3
1
AC
Output
T$_1$
4
2
C$_5$
C$_2$

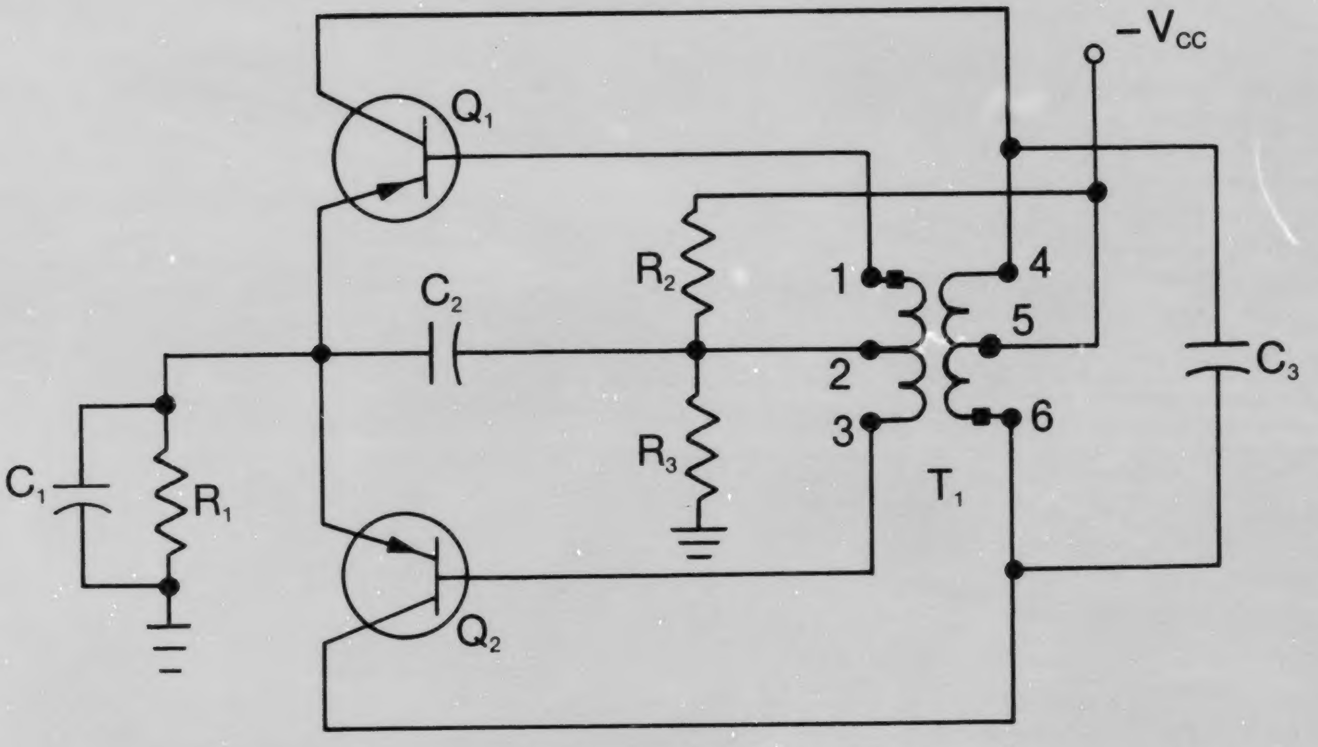
TM #4

GIE - 285-B

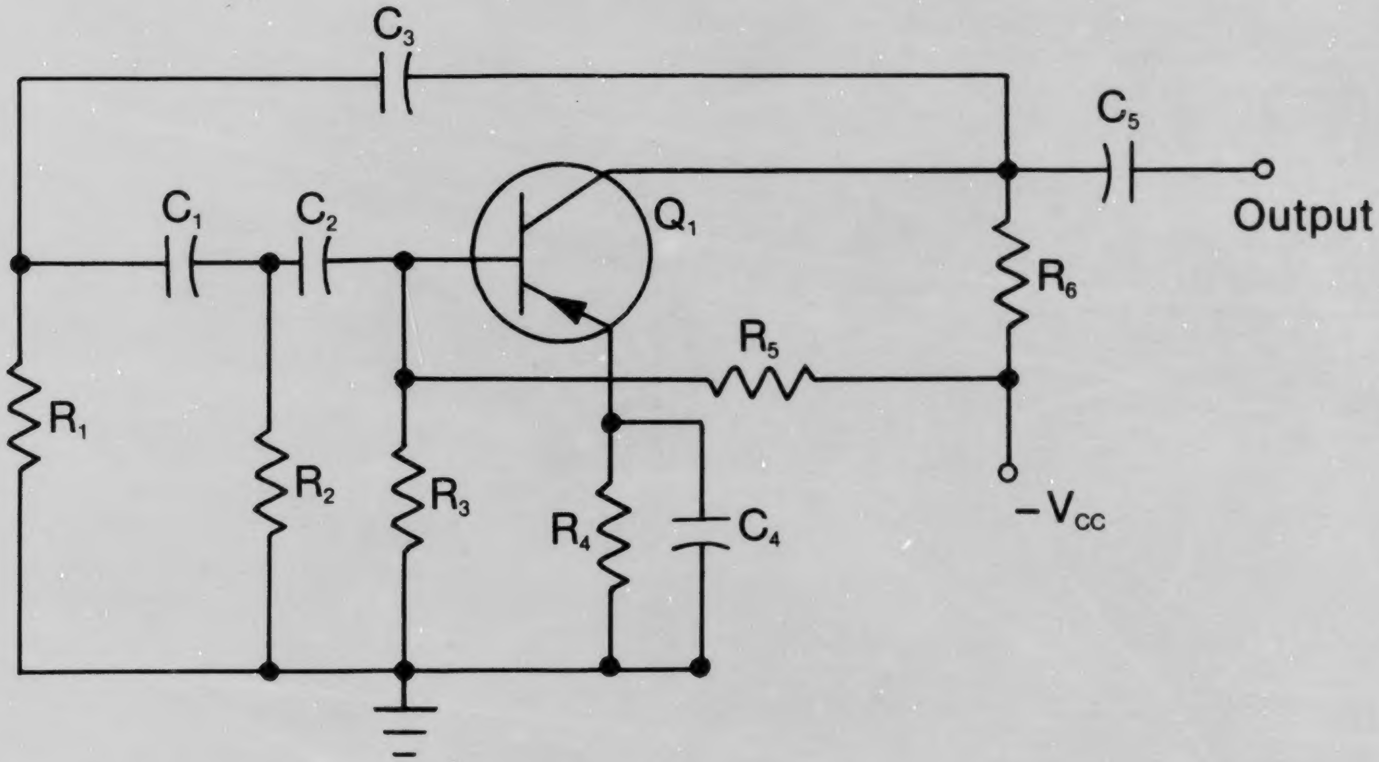
Crystal Oscillator


C_{cb}
C_2
L_1
Q_1
XTL_1
R_1
R_2
C_1
$+V_{CC}$

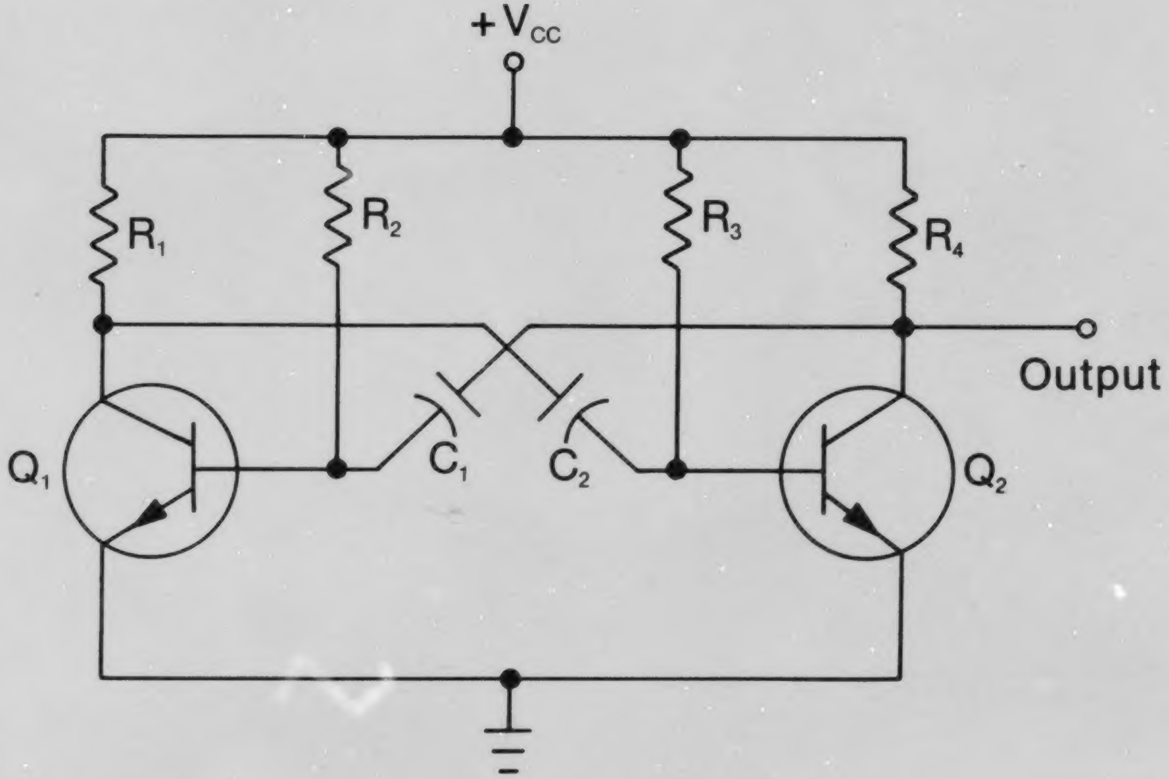
Push/Pull Oscillator


–V_CC
Q1
Q2
C1
R1
C2
R2
R3
C3
T1
1
2
3
4
5
6

RC Phase-Shift Oscillator


C₃
C₅
C₁
C₂
Q₁
Output
R₆
R₅
R₁
R₂
R₃
R₄
C₄
−V_CC

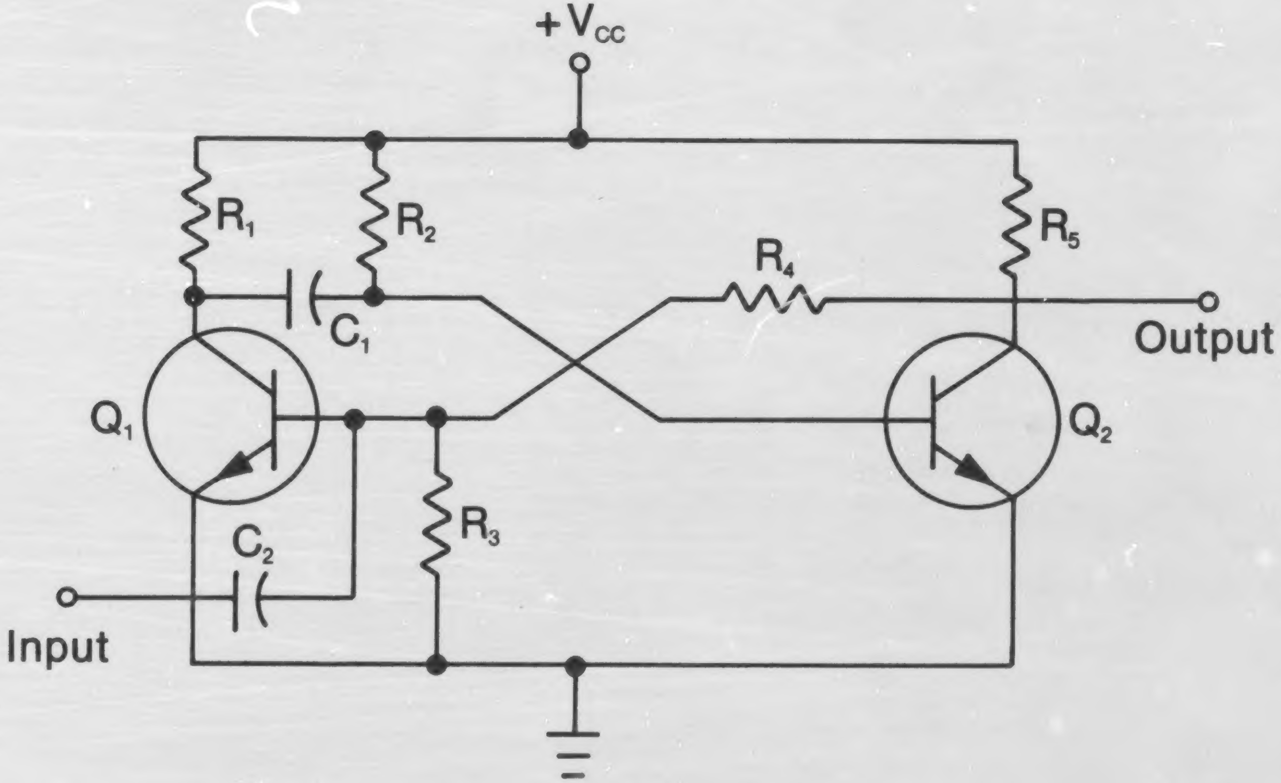
Astable Multivibrator


+V_CC
R1
R2
R3
R4
Output
C1
C2
Q1
Q2

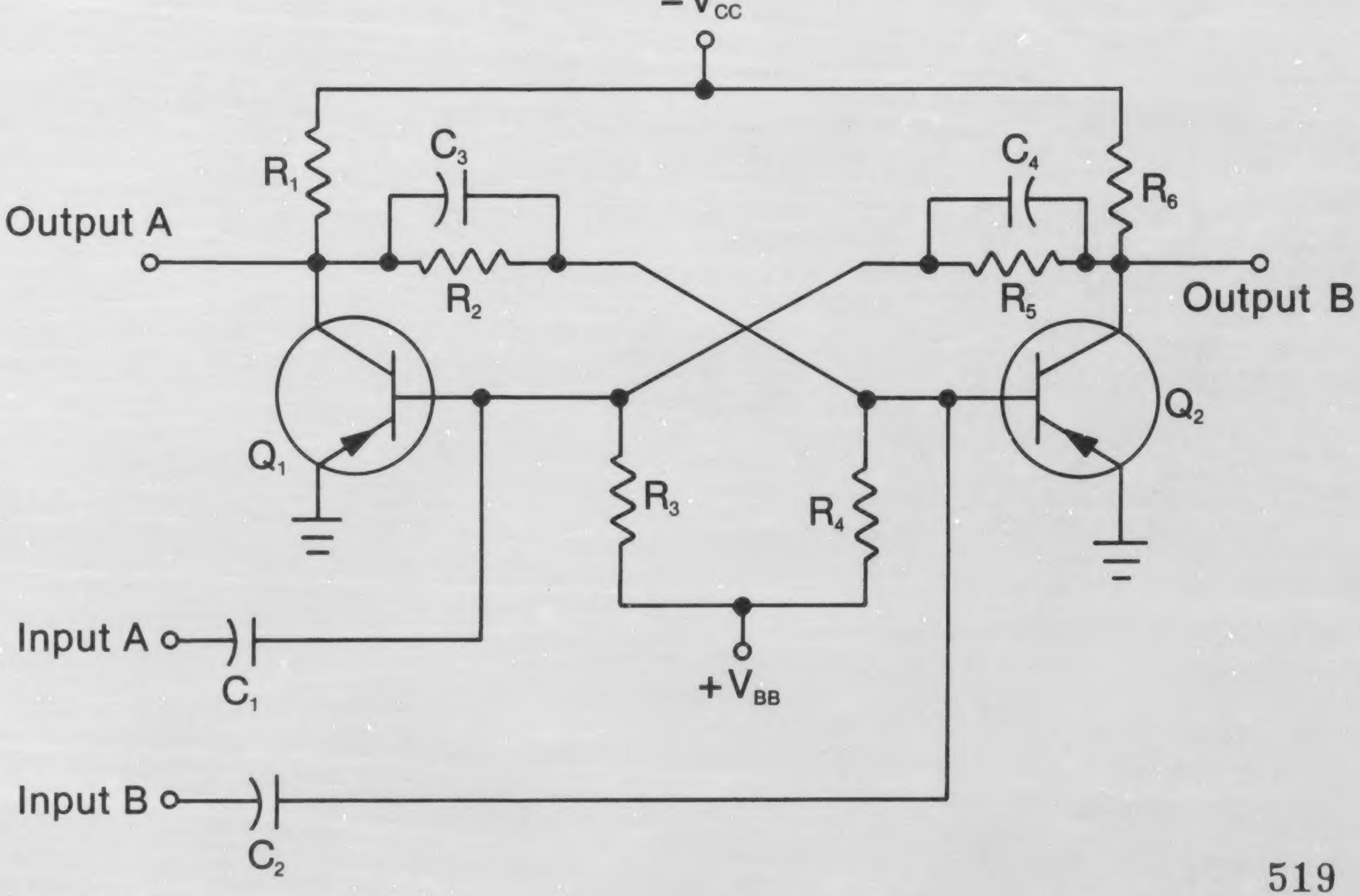
TM #8

GIE - 293-B

Monostable Multivibrator


+V$_{CC}$
R$_1$
R$_2$
R$_5$
R$_4$
C$_1$
Output
Q$_1$
Q$_2$
R$_3$
C$_2$
Input

Bistable Multivibrator


–V_CC
R_1
C_3
C_4
R_6
Output A
R_2
R_5
Output B
Q_1
Q_2
R_3
R_4
Input A
C_1
+V_BB
Input B
C_2

BASIC OSCILLATOR AND MULTIVIBRATOR CIRCUITS
UNIT IV

JOB SHEET #1 — ANALYZE A TUNED-COLLECTOR TUNED-BASE OSCILLATOR

I. Equipment and materials

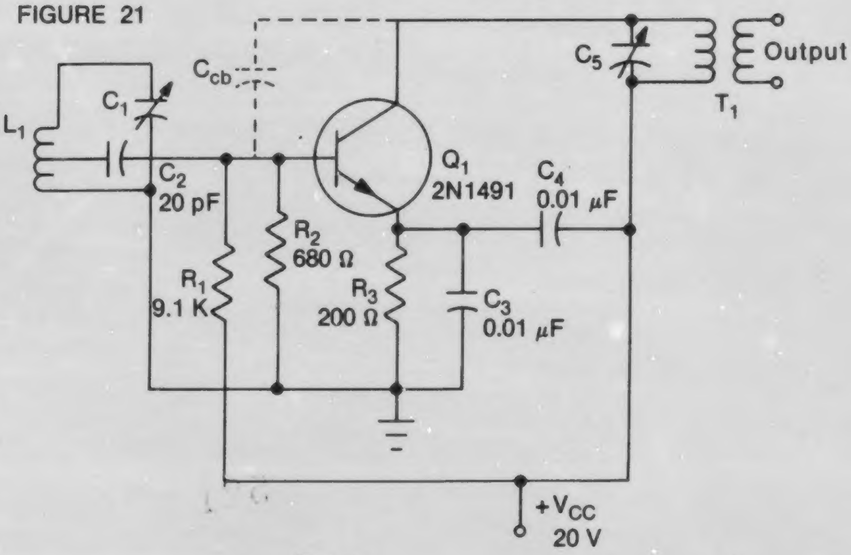
- A. Oscilloscope
- B. Power supply, 0 to 25 VDC
- C. Transistor, 2N1491 or equivalent
- D. Two capacitors, 20 picofarad, 25 VDC
- E. Two capacitors, 0.01 microfarad, 25 VDC
- F. Two decade boxes (shown as C1 and C5 in Figure 21)
- G. Resistor, 9.1 kohm, 1/2 watt
- H. Resistor, 680 ohm, 1/2 watt
- I. Resistor, 200 ohm, 1/2 watt
- J. Two inductors, 10 to 100 millihenrys
- K. Breadboard
- L. Test leads

II. Procedure

- A. Construct circuit and connect the tuned-collector tuned-base oscillator as shown in Figure 21, but do not turn on power supply

  (NOTE: Have instructor check circuit before proceeding.)

FIGURE 21


C_{cb}
C_1
L_1
C_2
20 pF
R_1
9.1 K
R_2
680 Ω
R_3
200 Ω
C_3
0.01 μF
Q_1
2N1491
C_4
0.01 μF
C_5
Output
T_1
$+V_{CC}$
20 V

JOB SHEET #1

B. Be sure that power supply voltage is adjusted to zero; then turn on/off switch to the ON position

C. Adjust C1 and C5 decade boxes to 22 microfarads

D. Turn on power supply and adjust voltage to 20 volts DC

E. Connect oscilloscope to output transformer L2

F. Measure frequency of output signal; record

Frequency = ____________________

G. Observe oscilloscope presentation while adjusting the C5, L2 capacitance above and below 22 microfarads

1. What was the indication on the oscilloscope?

2. Why did the above indications occur?

3. If C1, L1 capacitance were increased and decreased, what would be the results?

H. Vary C1, L1 capacitance up and down; what actually happens?

(NOTE: Discuss your results with the instructor.)

I. Disconnect oscilloscope

J. Disconnect circuit

K. Put away equipment and materials

BASIC OSCILLATOR AND MULTIVIBRATOR CIRCUITS
UNIT IV

JOB SHEET #2 — ANALYZE A CRYSTAL OSCILLATOR

I. Equipment and materials

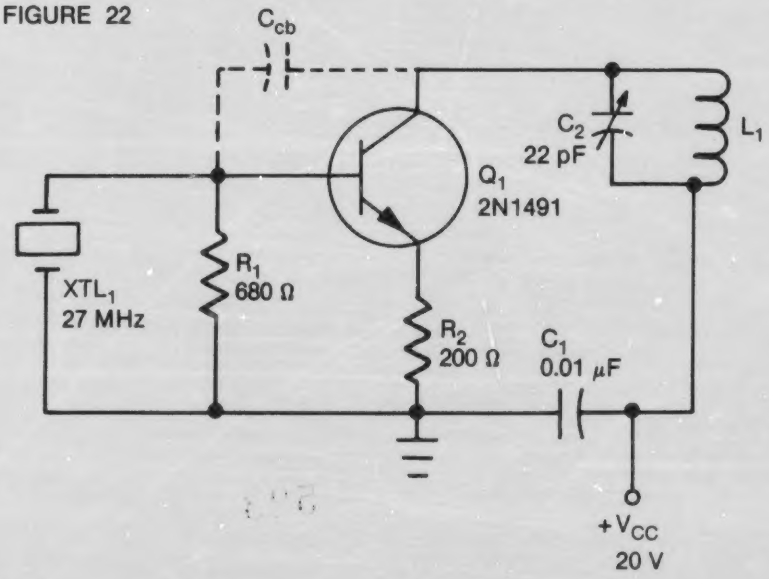
- A. Oscilloscope
- B. Power supply, 0 to 25 VDC
- C. Transistor, 2N1491 or equivalent
- D. Crystal, 27 megahertz
- E. Capacitor, 0.01 microfarad
- F. Variable capacitor, 22 picofarad
- G. Resistor, 680 ohm, 1/2 watt
- H. Resistor, 200 ohm, 1/2 watt
- I. Output transformer
- J. Breadboard
- K. Test leads

II. Procedure

- A. Construct circuit and connect crystal oscillator as shown in Figure 22, but do not turn on power supply

  (NOTE: Have instructor check circuit before proceeding.)

FIGURE 22


C_{cb}
C_2
22 pF
L_1
Q_1
2N1491
XTL_1
27 MHz
R_1
680 Ω
R_2
200 Ω
C_1
0.01 μF
$+V_{CC}$
20 V

JOB SHEET #2

B. Be sure that power supply voltage is adjusted to zero; then turn on/off switch to the ON position

C. Turn on power supply and adjust voltage to 20 volts DC

D. Connect oscilloscope to output transformer L1

E. Adjust variable capacitor C2 until output-signal presentation is steady with minimum distortion

F. Measure frequency of output signal; record

1. Frequency = ______________________________

2. How does this signal frequency compare to the signal frequency of the tuned-collector tuned-base oscillator in Job Sheet #1?

   ____

   ____

   (NOTE: The frequency of both circuits should be approximately the same because the crystal frequency is the same as the LC tank frequency of the tuned-collector tuned-base circuit.)

G. Vary capacitor C2 while observing the output signal

1. Does the output signal vary? ______________________________

2. Why or why not? ______________________________

   ____

   ____

   (NOTE: Discuss your results with the instructor.)

H. Disconnect oscilloscope

I. Disconnect circuit

J. Put away equipment and materials

BASIC OSCILLATOR AND MULTIVIBRATOR CIRCUITS
UNIT IV

JOB SHEET #3 — ANALYZE AN ASTABLE MULTIVIBRATOR

I. Equipment and materials

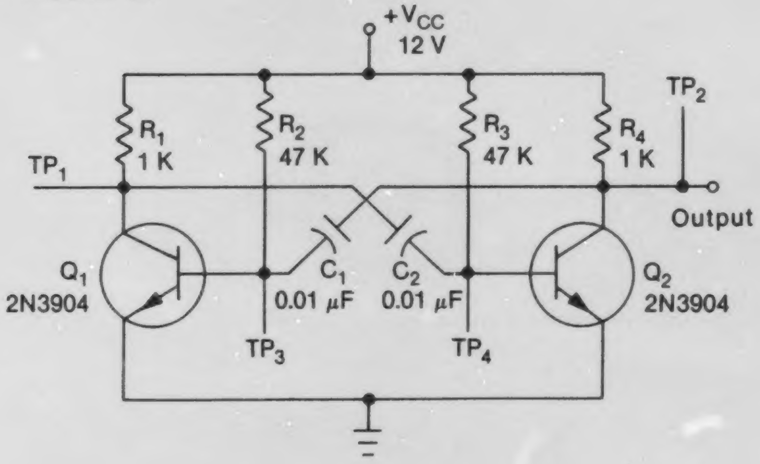
- A. Dual-trace oscilloscope
- B. DC power supply, 0 to 15 VDC
- C. Two transistors, 2N3904 or equivalent
- D. Two resistors, 1 kohm
- E. Two resistors, 47 kohm
- F. Two capacitors, 0.01 microfarad
- G. Breadboard
- H. Test leads

II. Procedure

- A. Construct the circuit and connect the astable multivibrator as shown in Figure 23, but do not turn on power supply

  (NOTE: Have instructor check circuit before proceeding.)

FIGURE 23



+V_{CC} 12 V
TP2
R1 1 K
R2 47 K
R3 47 K
R4 1 K
TP1
Output
Q1 2N3904
C1 0.01 μF
C2 0.01 μF
Q2 2N3904
TP3
TP4

JOB SHEET #3

B. Be sure that power voltage is adjusted to zero; then turn on/off switch to ON position

C. Turn on power supply and adjust voltage to 12 volts DC

D. Connect one channel of oscilloscope to TP1, the collector of Q1

E. Connect second channel of oscilloscope to TP2, the collector of Q2

F. On the sheet of graph paper on the following page, draw the wave forms in exact reference to each other as seen on oscilloscope

G. Remove test lead from TP2, and connect to TP3

H. Draw on the graph the wave form from TP3 in reference to those of TP1 and TP2

I. Remove test lead from TP1, and connect to TP4

J. Draw the wave form from TP4 in reference to those of TP1, TP2, and TP3

1. Are the wave forms from TP1 and TP2 in phase? ________________

   Why? ____

   ____

2. Are the wave forms from TP3 and TP4 in phase? ________________

   Why? ____

   ____

   ____

3. Are the wave forms from TP2 and TP3 in phase? ________________

   Why? ____

   ____

   ____

4. Are the wave forms from TP1 and TP3 in phase? ________________

   Why? ____

   ____

   ____

(NOTE: Discuss your results with the instructor.)

K. Disconnect oscilloscope

L. Disconnect circuit

M. Put away equipment and materials

JOB SHEET #3

BASIC OSCILLATOR AND MULTIVIBRATOR CIRCUITS
UNIT IV

TEST

NAME ________________________________ SCORE ______________

1. Match to their correct definitions terms associated with oscillators and multivibrators. Write the correct numbers in the blanks. Definitions continue on the following page.

_____a. Amplifier with controlled feedback that produces an alternating output signal

_____b. Feedback that reduces output by supplying an opposing voltage back to input of circuit

_____c. Reduction of oscillation amplitude

_____d. Assembly of resistors, capacitors, or coils; assembly contains two or more sections divided into ten equal parts, each section having ten times the value of the preceding section; by means of a ten-position selector switch, the assembly can be set to any desired value in its range

_____e. Feedback that reinforces output by supplying a boosting voltage back to input of circuit

_____f. Uniformly alternating output

_____g. Capacitor used to provide a comparatively low impedance path around a component

_____h. Circuit composed of an inductor and a capacitor in parallel used as a filtering circuit, a wave trap, a coupling circuit, or an oscillator frequency-determining circuit

_____i. Method of connecting a fraction of an output signal back to input of circuit

_____j. Electronic component composed of crystalline substance, such as quartz, which is cut and shaped to produce a specific frequency of oscillation when electrically excited

_____k. Making, breaking, or changing the connections in an electrical circuit

1. Damping
2. Positive feedback (regenerative)
3. Feedback
4. Oscillator
5. Crystal
6. RC time constant
7. Tank circuit
8. Oscillation
9. Negative feedback (degenerative)
10. Decade box
11. Bypass capacitor
12. Switching
13. Resonant frequency

TEST

______l. Time required for a capacitor to charge 63 percent of the voltage across it; equal to resistance times capacitance

______m. Frequency at which a circuit tends to vibrate or oscillate because of the capacitance and inductance combination

2. Match to their correct interpretations abbreviations associated with oscillators and multivibrators. Write the correct numbers in the blanks.

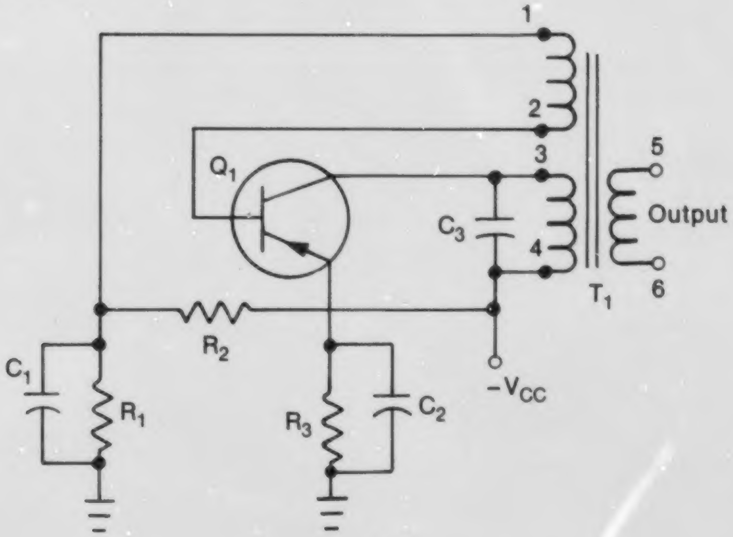
______a. Kilohertz
______b. Master clock
______c. Audio frequency, sonic frequency, sound frequency
______d. Radio frequency
______e. Hertz
______f. Base supply voltage
______g. Variable-frequency oscillator
______h. Inductive/capacitive circuit
______i. Crystal
______j. High frequency
______k. Gigahertz
______l. Beat-frequency oscillator
______m. Collector supply voltage
______n. Oscillator
______o. Megahertz
______p. Resistive/capacitive circuit
______q. Voltage-controlled oscillator
______r. Flip-flop
______s. Single shot
______t. Test point
______u. Collector-base interterminal capacitance

1. VCO
2. GHz
3. HF
4. V_{BB}
5. BFO
6. rf
7. MHz
8. SS
9. LC
10. XTL
11. Hz
12. VFO
13. RC
14. V_{CC}
15. kHz
16. Osc
17. af
18. MC
19. FF
20. TP
21. C_{cb}

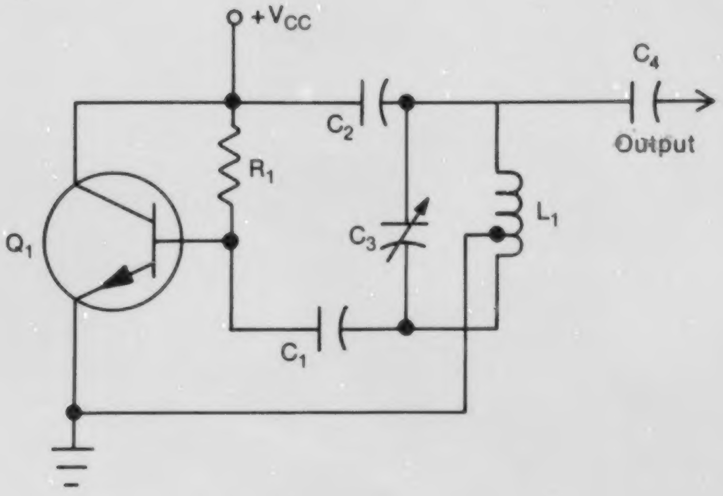
TEST

3. Identify oscillator circuit diagrams. Write the correct names in the blanks.

Colpitts	**Hartley**
RC phase shift	**Tuned-collector tuned-base**
Crystal	**Armstrong**
Push/pull	

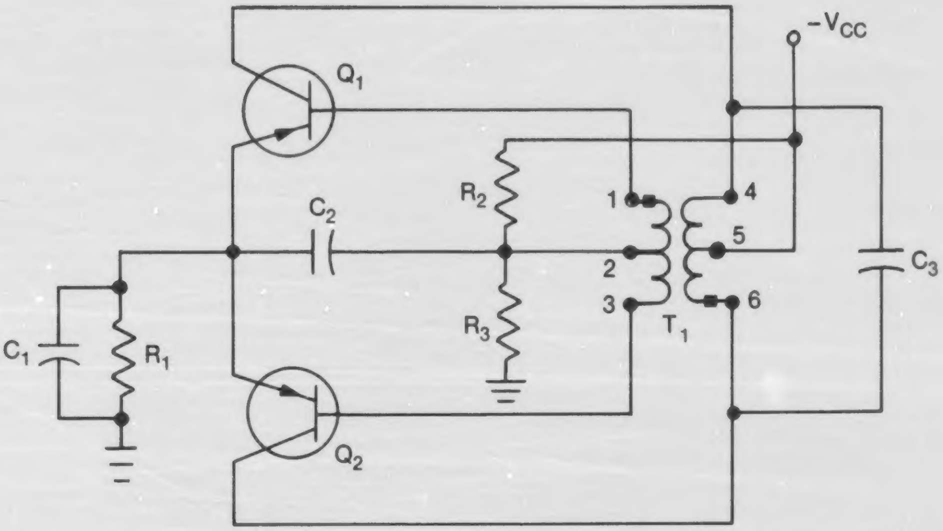

1
2
3
4
5
6
Q_1
C_3
Output
T_1
R_2
C_1
R_1
R_3
C_2
$-V_{CC}$

a. ______________________________


$+V_{CC}$
C_4
C_2
Output
R_1
L_1
Q_1
C_3
C_1

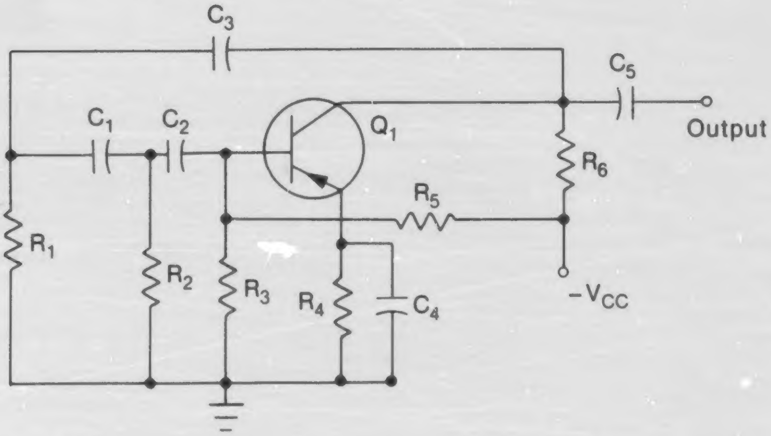
b. ______________________________

TEST



Q1
-VCC
C2
R2
1
4
5
2
3
6
C3
C1
R1
R3
T1
Q2

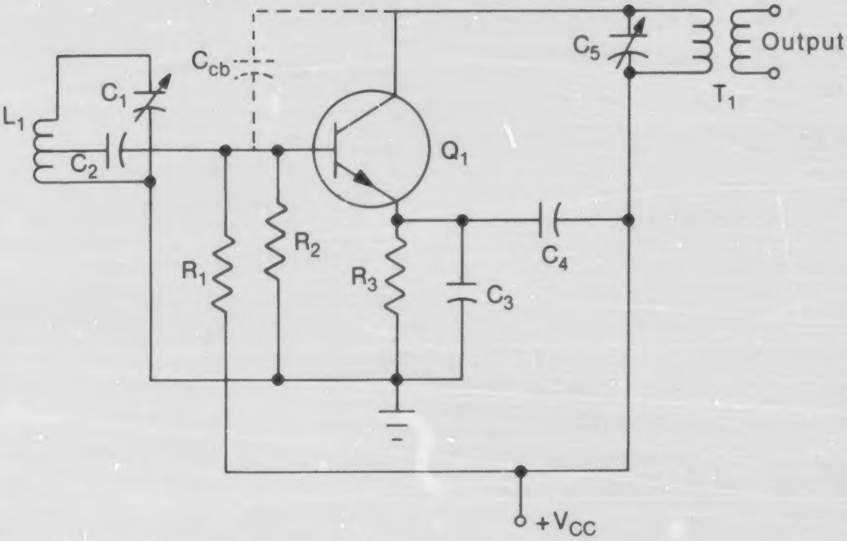
c. ______________________________



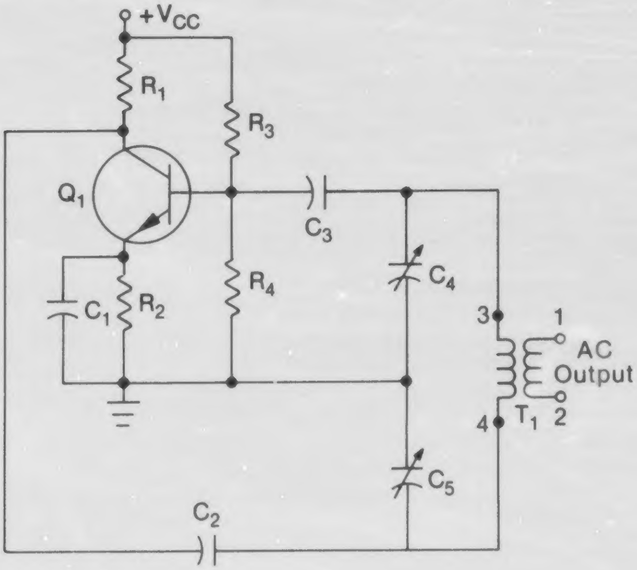
C3
C5
C1
C2
Q1
Output
R6
R5
R1
R2
R3
R4
C4
-VCC

d. ______________________________

TEST

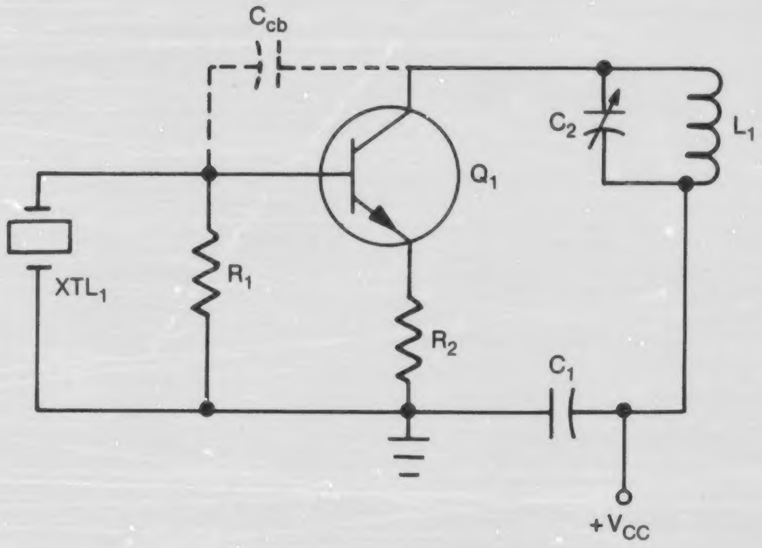

Ccb
C1
L1
C2
R1
R2
Q1
R3
C3
C4
C5
Output
T1
+VCC

e. ______________________________


+VCC
R1
R3
Q1
C3
C4
R4
C1
R2
3
1
AC
Output
4
T1
2
C5
C2

f. ______________________________

TEST


C_{cb}
C_2
L_1
Q_1
XTL_1
R_1
R_2
C_1
$+V_{CC}$

g. ________________________________

4. State the frequency-determining components and the feedback paths of various oscillators.

a. Armstrong

1) Frequency — ________________________________

____

2) Feedback — ________________________________

____

b. Colpitts

1) Frequency — ________________________________

____

2) Feedback — ________________________________

____

c. Push/pull

1) Frequency — ________________________________

____

2) Feedback — ________________________________

____

TEST

d. Crystal

1) Frequency — ____

____

2) Feedback — ____

____

e. Tuned-collector tuned-base

1) Frequency — ____

____

2) Feedback — ____

____

f. Hartley

1) Frequency — ____

____

2) Feedback — ____

____

g. RC phase shift

1) Frequency — ____

____

2) Feedback — ____

____

5. Match types of multivibrators to their correct descriptions. Write the correct numbers in the blanks.

_____a. Circuit having only one stable state from which it can be triggered to change; after a predetermined time, it returns to its original state

_____b. Circuit that continually alternates between two unstable states at a frequency determined by the circuit components

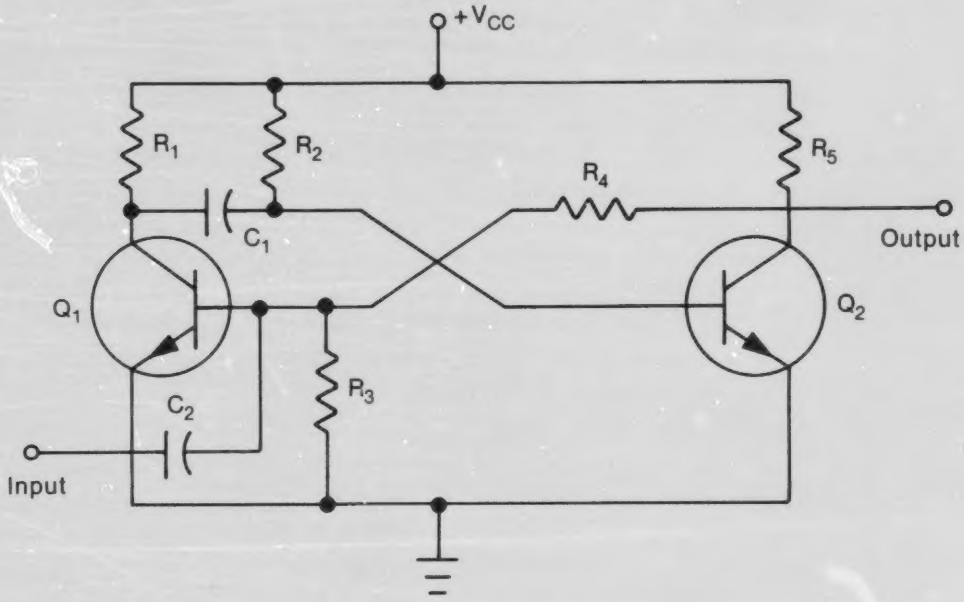
_____c. Circuit having two stable states that will stay in either state until triggered to switch to the opposite state

1. Astable
2. Monostable
3. Bistable

TEST

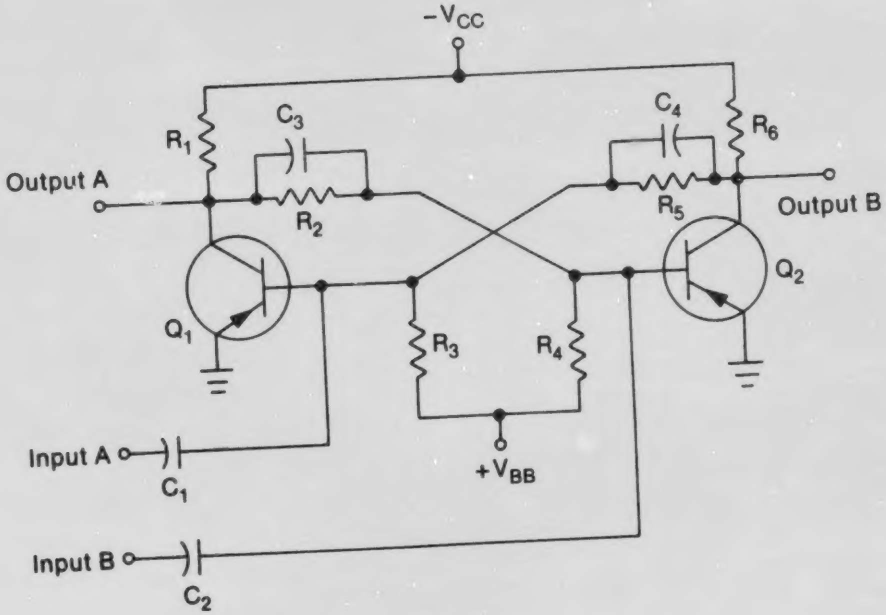
6. Identify multivibrator circuit diagrams. Write the correct names in the blanks.

Astable
Monostable
Bistable

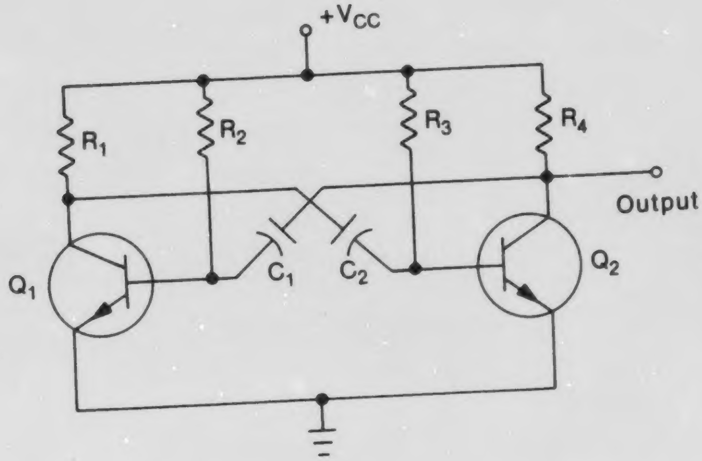

+V_{CC}
R_1
R_2
R_4
R_5
C_1
Output
Q_1
Q_2
R_3
C_2
Input

a. ____________________

TEST


−VCC
R1
C3
R2
Output A
Q1
R3
R4
+VBB
C4
R6
R5
Output B
Q2
Input A
C1
Input B
C2

b. ____________________

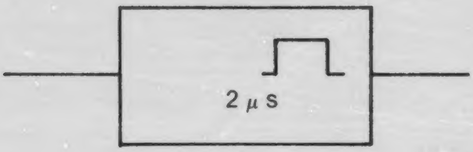

+VCC
R1
R2
R3
R4
Output
Q1
C1
C2
Q2

c. ____________________

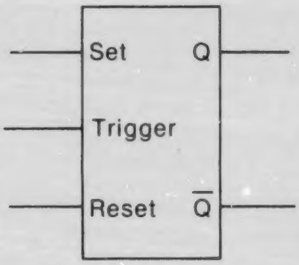
TEST

7. Identify multivibrator logic and block-diagram symbols. Write the correct names in the blanks. A name may be used more than once.

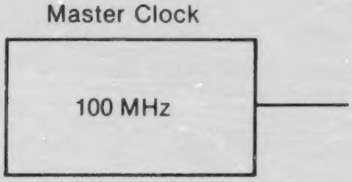
Bistable
Monostable
Astable



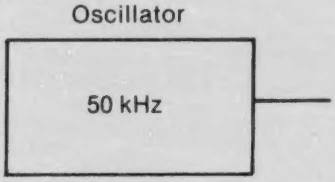
a. ______________________



b. ______________________



c. ______________________



d. ______________________

8. Match input and output descriptions to correct types of multivibrator. Write the correct numbers in the blanks. Numbers may be used more than once.

______a. Input — Single input that can occur at random

______b. Output — Continuous, uniform square wave

______c. Input — None

______d. Output — Usually two that are opposite

______e. Set input — Forces one transistor on

______f. Output — One rectangular pulse for each input positive transition

______g. Reset input — Forces opposite transistor on

______h. Toggle input — Forces state to change

1. Astable
2. Monostable
3. Bistable

TEST

(NOTE: Test question 9 lists the job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

9. Demonstrate the ability to

   a. Analyze a tuned-collector tuned-base oscillator.

   b. Analyze a crystal oscillator.

   c. Analyze an astable multivibrator.

BASIC OSCILLATOR AND MULTIVIBRATOR CIRCUITS
UNIT IV

ANSWERS TO TEST

1.	a.	4	h.	7
	b.	9	i.	3
	c.	1	j.	5
	d.	10	k.	12
	e.	2	l.	6
	f.	8	m.	13
	g.	11		

2.	a.	15	g.	12	m.	14	s.	8
	b.	18	h.	9	n.	16	t.	20
	c.	17	i.	10	o.	7	u.	21
	d.	6	j.	3	p.	13		
	e.	11	k.	2	q.	1		
	f.	4	l.	5	r.	19		

3.	a.	Armstrong	e.	Tuned-collector tuned-base
	b.	Hartley	f.	Colpitts
	c.	Push/pull	g.	Crystal
	d.	RC phase shift		

4. a. Armstrong

   1) Frequency — C3 and T1 (terminals 3 and 4) resonant frequency

   2) Feedback — T1 (terminals 1 and 2) to Q1 base

ANSWERS TO TEST

b. Colpitts
   1) Frequency — C1, C2, and T1 (terminals 3 and 4) resonant frequency
   2) Feedback — C3 to base of Q1

c. Push/pull
   1) Frequency — C2 and T1 (terminals 4 and 6) resonant frequency
   2) Feedback — T1 (terminals 1, 2, and 3) to Q1 and Q2 bases

d. Crystal
   1) Frequency — XTL1 harmonic
   2) Feedback — Q1 collector to base capacitance (C_{cb})

e. Tuned-collector tuned-base
   1) Frequency — C1 and L1 resonant frequency matched to C5 and L2
   2) Feedback — Q1 collector to base capacitance (C_{cb})

f. Hartley
   1) Frequency — C2 and L1 resonant frequency
   2) Feedback — C3 to base of Q1

g. RC phase shift
   1) Frequency — RC time constant of C1 and R1 through C3 and R3
   2) Feedback — C1, C2, C3 to base of Q1

5. a. 2
   b. 1
   c. 3

6. a. Monostable
   b. Bistable
   c. Astable

ANSWERS TO TEST

7. a. Monostable
   b. Bistable
   c. Astable
   d. Astable

8. a. 2
   b. 1
   c. 1
   d. 3
   e. 3
   f. 2
   g. 3
   h. 3

9. Performance skills evaluated to the satisfaction of the instructor

INTEGRATED CIRCUITS
UNIT V

UNIT OBJECTIVE

After completing this unit, the student should be able to construct and analyze circuitry involving integrated-circuit devices. The student will show this knowledge by completing assignment sheets, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with integrated circuits to their correct definitions.
2. Match abbreviations and acronyms associated with integrated circuits to their correct interpretations.
3. Name commonly used integrated-circuit packages.
4. Label features of a typical dual in-line package integrated circuit.
5. Label number-one pin on integrated circuits.
6. Name the principal elements contained in integrated circuits.
7. State advantages of integrated circuits as compared to discrete components in equivalent circuitry.
8. Match integrated-circuit troubleshooting equipment to their correct applications.
9. Distinguish between linear integrated-circuit applications and digital integrated-circuit applications.
10. List guidelines for technicians to follow when working with integrated circuits.
11. Demonstrate the ability to
    a. Analyze the integrated-circuit operational amplifier.
    b. Construct a timer circuit using a 555 integrated circuit.

INTEGRATED CIRCUITS
UNIT V

SUGGESTED ACTIVITIES

I. Suggested activities

  A. Make transparencies.

  B. Provide students with objective sheet.

  C. Discuss unit and specific objectives. State need for knowledge in each area.

  D. Provide students with information, assignment, and job sheets.

  E. Discuss information and assignment sheets.

  F. Demonstrate and discuss procedures outlined in job sheets.

  G. Show students various integrated circuits and explain the pin formations.

  H. Emphasize the importance of not touching or shorting the integrated circuit.

  I. Obtain semiconductor data manuals and demonstrate their use so that students may complete Assignment Sheet #2.

  J. Show students integrated circuits or pictures of minute integrated-circuit details.

  K. Remove the cover plate from a defective microprocessor integrated circuit and let students view it with a magnifying glass or microscope.

  L. Decide whether your students are prepared at this stage of training to complete Job Sheet #2. If not, preconstruct the circuit for them, and have them complete the data tables.

  M. Give test.

  N. Reteach and retest if necessary.

II. Instructional materials

  A. Objective sheet

  B. Suggested activities

  C. Information sheet

SUGGESTED ACTIVITIES

D. Transparency masters

  1. TM #1 — Commonly Used Integrated-Circuit Packages (Approximate Actual Size)
  2. TM #2 — Features of a Typical Dual In-Line Package Integrated Circuit

E. Assignment sheets

  1. Assignment Sheet #1 — Label Features of a Typical Dual In-Line Package Integrated Circuit
  2. Assignment Sheet #2 — Use Data Manuals to Label Integrated-Circuit Number-One Pin

F. Answers to assignment sheets

G. Job sheets

  1. Job Sheet #1 — Analyze the Integrated-Circuit Operational Amplifier
  2. Job Sheet #2 — Construct a Timer Circuit Using a 555 Integrated Circuit

H. Test

I. Answers to test

III. Unit references

A. Allied Electronics. *Engineering Manual and Purchasing Guide, #790.* Fort Worth, Texas: Allied Electronics, 1979.

B. Berlin, Howard M. *The 555 Timer Applications Sourcebook, with Experiments: Techniques, Applications, and Experiments Using the 555 IC Timer.* Derby, Connecticut: E & L Instruments, Inc., 1981.

C. *Byte,* Vol. IV, No. 3 (March, 1979), p. 19.

D. Chute, George M., and Robert D. Chute. *Electronics in Industry,* 5th ed. New York: McGraw-Hill Book Company, 1979.

E. Deboo, Gordon J., and Clifford N. Burrows. *Integrated Circuits and Semiconductor Devices,* 2nd ed. New York: McGraw-Hill Book Company, 1977.

F. *Digital Design,* Vol. IX, No. 11 (November, 1979), p. 55.

G. *EDN,* Vol. XXIV, No. 18 (October 5, 1979), p. 126.

SUGGESTED ACTIVITIES

H. "Inside an Integrated Circuit." *IEEE Spectrum,* Vol. XVIII, No. 1 (January, 1981), p. 63.

I. Mims, Forrest M. *Integrated Circuits Projects,* 2nd ed., Vol. 4. Texas: Radio Shack, 1976.

J. "New Generation IC Development System." *Digital Design,* Vol. IX, No. 11 (November, 1979), p. 44.

K. "The One-Chip Computer: Offspring of the Transistor." *IEEE Spectrum,* Vol. XVII, No. 5 (May, 1980), p. 6.

L. Pasahow, Edward. *Integrated Circuits for Electronics Technicians.* New York: McGraw-Hill Book Company, 1980.

M. Shrader, Robert L. *Electronic Communications,* 4th ed. New York: McGraw-Hill Book Company, 1980.

N. Zbar, Paul B., and Joseph G. Sloop. *Electricity-Electronics Fundamentals.* New York: McGraw-Hill Book Company, 1977.

INTEGRATED CIRCUITS
UNIT V

INFORMATION SHEET

I. Terms and definitions

A. Integrated circuit — Device constructed of multiple segments of semiconductor materials and junctions containing the equivalent function of such discrete devices as transistor and diode junctions, resistors, and capacitors

B. Substrate — Base material of an integrated-circuit chip upon which the circuitry is formed

(NOTE: Some integrated circuits have a pin connection to the substrate, which drains static charges, or to references to a voltage bias.)

C. Discrete device — Component composed of one functional element as opposed to an integrated-circuit device composed of many elements

EXAMPLES: Transistor, diode, silicon-controlled rectifier, resistor

D. Digital device — Component that operates at specific voltage levels, switching outputs between those levels according to specific input levels

(NOTE: Most digital devices operate at one of two levels.)

E. Binary — Having two voltage levels of inputs and outputs

F. Analog device — Component that operates at any voltage level within a range

G. Linear device — Component that has the same gain or reaction to the input over the operating range regardless of frequency or environmental factors such as temperature and humidity

H. Small-scale integration — Devices containing the composite of several discrete components in a small, integrated form

I. Medium-scale integration — Devices containing the composite of dozens of discrete components in a small, integrated form

J. Large-scale integration — Devices containing the composite of hundreds of components in a small, integrated form

INFORMATION SHEET

K. Very large-scale integration — Devices containing the composite of thousands of components in a small, integrated form

(NOTE: A microprocessor integrated circuit may have 30,000 devices integrated into a chip less than one-fourth the size of a paper clip.)

L. Hardware — Circuitry, wiring, and devices of an electronic instrument or computer

M. Chip — Integrated circuit

N. Monolithic integrated circuit — Device in which active elements (such as transistors) and passive elements (such as resistors) are integrated into a continuous single component on a single substrate

O. Hybrid integrated circuit — Device in which discrete components or integrated circuits are integrated into a package

II. Abbreviations and acronyms associated with integrated circuits

A. IC — Integrated circuit

B. SSI — Small-scale integration

C. MSI — Medium-scale integration

D. LSI — Large-scale integration

E. VLSI — Very large-scale integration

F. RTL — Resistor/transistor logic

G. DTL — Diode/transistor logic

H. TTL,T^{2}L — Transistor/transistor logic

I. ECL — Emitter-coupled logic

J. MOS — Metal-oxide semiconductor

K. CMOS — Complementary metal-oxide semiconductor

L. NMOS — n-type metal-oxide semiconductor

M. PMOS — p-type metal-oxide semiconductor

N. MOSFET — Metal-oxide semiconductor field-effect transistor

O. V_{DD} — Drain supply voltage

INFORMATION SHEET

P. V_{SS} — Source supply voltage

Q. V_{CC} — Collector supply voltage

R. DIP — Dual in-line package

S. DCTL — Direct-coupled transistor logic

T. IIL, I^2L — Integrated injection logic

(NOTE: There are dozens of logic designs [such as T^2L and I^2L] too numerous to cover in this unit. Students and technicians should consult manufacturer's reference manuals to check the proper handling and testing of particular devices.)

U. PCB — Printed circuit board

V. Mil spec — Military specification

(NOTE: Industry often refers to *mil spec* as a requirement for quality and design.)

III. Commonly used integrated-circuit packages (Transparency #1)

A. Dual in-line

B. Case

IV. Features of a typical dual in-line package integrated circuit (Transparency #2; Assignment Sheet #1)

A. Manufacturer's name or logo

B. Part number

1. Prefix

(NOTE: The prefix varies among manufacturers.)

2. Number

(NOTE: The number may be identical or almost identical among manufacturers.)

3. Suffix

(NOTE: The suffix is the code for package material, temperature range, and so forth. It varies among manufacturers.)

C. Date code

(NOTE: The date code is a numerical combination of the year and the week of manufacture.)

D. Notch, small indentation, or tab

E. Pins

(NOTE: Pins are numbered consecutively down one side and up the other side.)

F. Distance between pin centers

G. Case

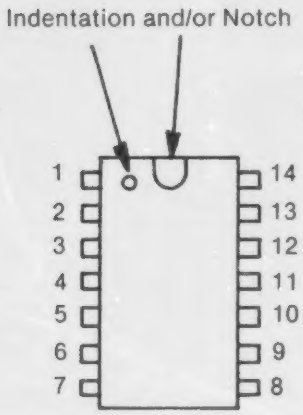
H. Top

V. Finding number-one pin on integrated circuits (Assignment Sheet #2)

A. Dual in-line package

1. DIP IC — When viewing from top with notch or indentation at top, the first top-left pin is pin number one (Figure 1)

FIGURE 1

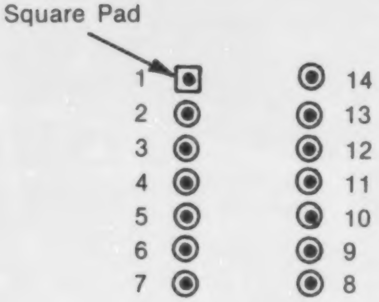


INFORMATION SHEET

2. DIP PCB pads — Pin number one may be marked with square, triangle, or other symbol; count same as on an IC when viewing PCB from component side (Figure 2)

   (NOTE: Most PCBs have components on only one side. That side is referred to as the *component side.* The other side is called the *circuit side.* Pads and runs may be on both sides or sandwiched in layers in between.)

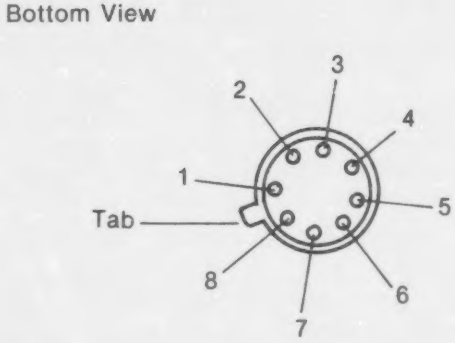
FIGURE 2


Square Pad
1
2
3
4
5
6
7
14
13
12
11
10
9
8

B. Case package

1. Tab between pins — When viewing from the bottom, the pin following the tab is pin number one (Figure 3)

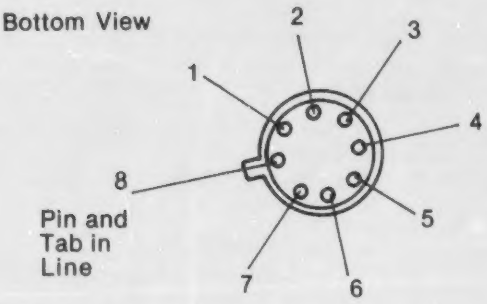
FIGURE 3


Bottom View
3
2
4
1
5
Tab
8
6
7

INFORMATION SHEET

2. Tab in line with pin — When viewing from the bottom, the pin following the tab is pin number one (Figure 4)

FIGURE 4



VI. Principal elements contained in integrated circuits

A. Transistors

B. Diodes

C. Resistors

D. Capacitors

E. Photosensitive elements

VII. Advantages of integrated circuits as compared to discrete components in equivalent circuitry

A. Are more reliable

(NOTE: Less component-to-component circuitry improves reliability and reduces cost of electronic equipment.)

B. Generally require lower power

C. Are less costly

D. Are smaller, more compact, and lighter in weight

(NOTE: Integrated-circuit devices have made space travel and exploration possible by virtue of their small size and light weight. They have also made powerful computers less costly and smaller.)

INFORMATION SHEET

E. Are simpler and faster to design and fabricate

F. Provide simplified compatibility of interconnecting circuitry

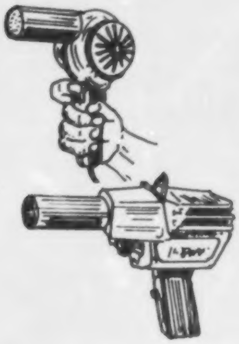
(NOTE: Integrated circuits of the same logic, such as TTL, can be readily interconnected without much concern for impedance matching, various voltage requirements, or switching-speed variations.)

VIII. Integrated-circuit troubleshooting-equipment applications (Figures 5-11)

A. Heat gun — Used to heat components while troubleshooting to find intermittent failures due to heat-sensitive integrated circuits

EXAMPLES:

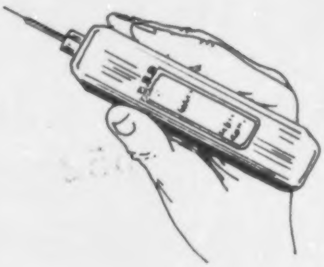
FIGURE 5



B. Digital IC logic probe — Used to detect high or low digital state of inputs and outputs

EXAMPLE:

FIGURE 6

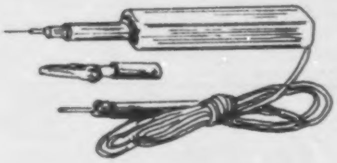


INFORMATION SHEET

C. IC voltage probe — Used to check IC leads for voltage

EXAMPLE:

FIGURE 7

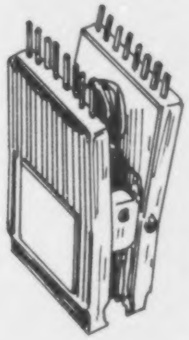


D. IC test clip — Used to clamp on to DIP ICs to make oscilloscope and other probe measurements easier

(NOTE: Clip may also be used as a heat sink during soldering. Other similar probes are available with light-emitting diode indicators for each pin to show either high or low digital state.)

EXAMPLE:

FIGURE 8

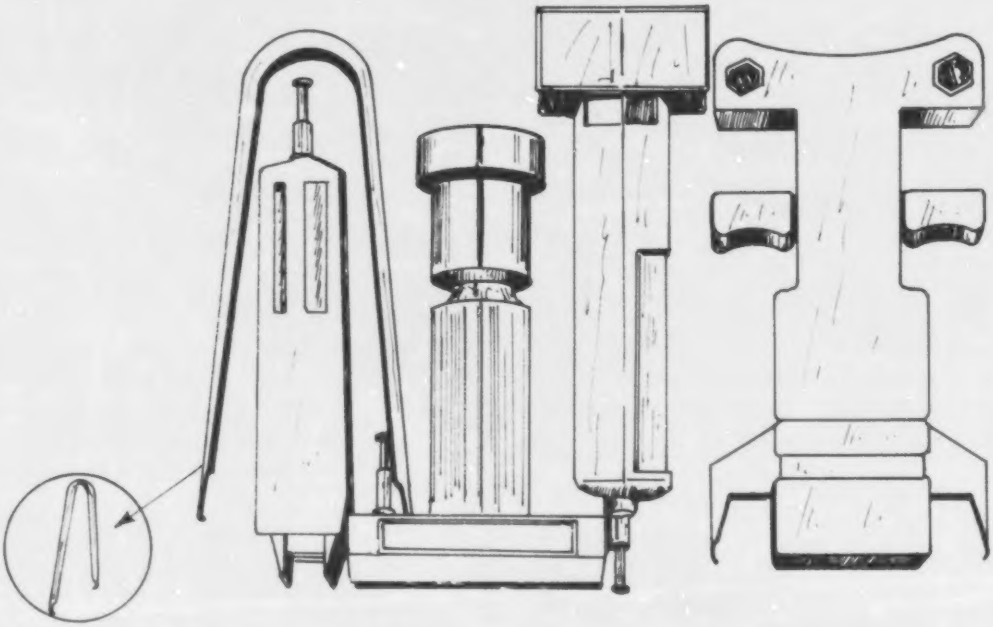


INFORMATION SHEET

E. DIP insertion and extraction tools — Used to install and remove DIP ICs without bending pins

EXAMPLES:

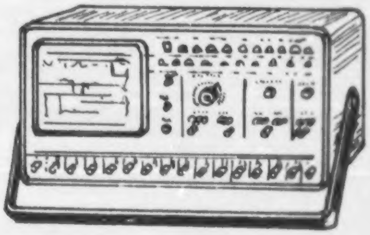
FIGURE 9



F. Logic analyzer — Used to view several IC inputs and outputs at a time; displays digital codes, timing-diagram wave forms, or digital maps of sequences

EXAMPLE:

FIGURE 10

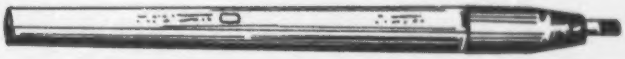


Sixteen-Channel Logic Analyzer

G. IC current probe — Used to trace current paths through circuits

EXAMPLE:

FIGURE 11



INFORMATION SHEET

IX. Linear and digital integrated-circuit applications

- A. Linear
  - 1. Amplifiers

    EXAMPLES: Operational amplifiers, differential amplifiers, driver amplifiers, buffer amplifiers
  - 2. Voltage control

    EXAMPLES: Voltage regulators, voltage references
  - 3. Analog control

    EXAMPLES: Dividers, summers, multipliers, integrators
  - 4. Interface circuits

    EXAMPLES: Analog-to-digital converters, digital-to-analog converters, digital-to-optical converters
- B. Digital
  - 1. Logic circuits

    EXAMPLES: AND gates, OR gates, adders
  - 2. Memory circuits

    EXAMPLES: Core memory, bubble memory, shift registers
  - 3. Counters

    EXAMPLES: Accumulators, clocks, timers

X. Guidelines for technicians to follow when working with integrated circuits

- A. Store ICs in antistatic containers

  (NOTE: A circuit may be easily destroyed by static electricity.)
- B. Wear static-grounded wrist strap
- C. Use low-wattage soldering iron

  (NOTE: A circuit requires special grounded and temperature-controlled soldering irons.)

INFORMATION SHEET

D. Avoid overheating components when soldering

E. Do not use acid solder, chloride fluxes, or paste fluxes

F. Do not remove ICs or PCBs with power on

G. Do not drop or subject ICs to mechanical shock

H. Do not apply signals to inputs when power is off

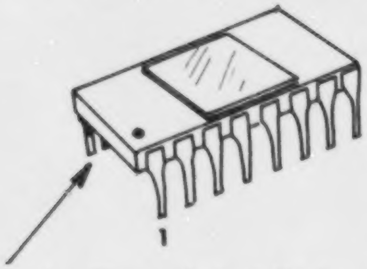
I. Consult reference manual for proper voltages and connection requirements

J. Use special test clips to avoid shorting between terminals

K. Do not use analog multimeters to test for shorts and open circuits

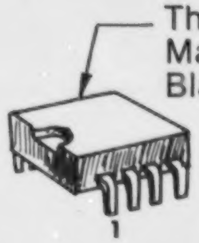
Commonly Used Integrated-Circuit Packages (Approximate Actual Size)

Ceramic Dual In-Line (DIP)



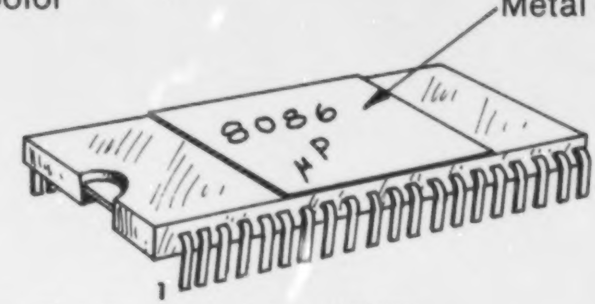
Ceramic (Porcelain-Like)
Material, Usually Gray or
White in Color

Thermal Plastic
Material, Usually
Black in Color



Eight-Pin Dual In-Line (DIP)

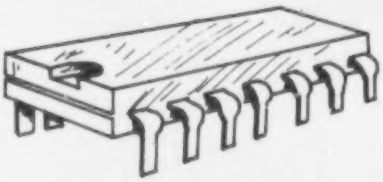
Metal Cover Plate



Forty-Pin Dual In-Line (DIP)

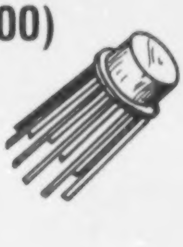
Typical Microprocessor (Computer on a Chip)
Example of Very Large-Scale Integration (VLSI)

(Note: Other pin configurations besides those shown here include six-, sixteen-, eighteen-, twenty-four-, and twenty-eight-pin DIPs.)

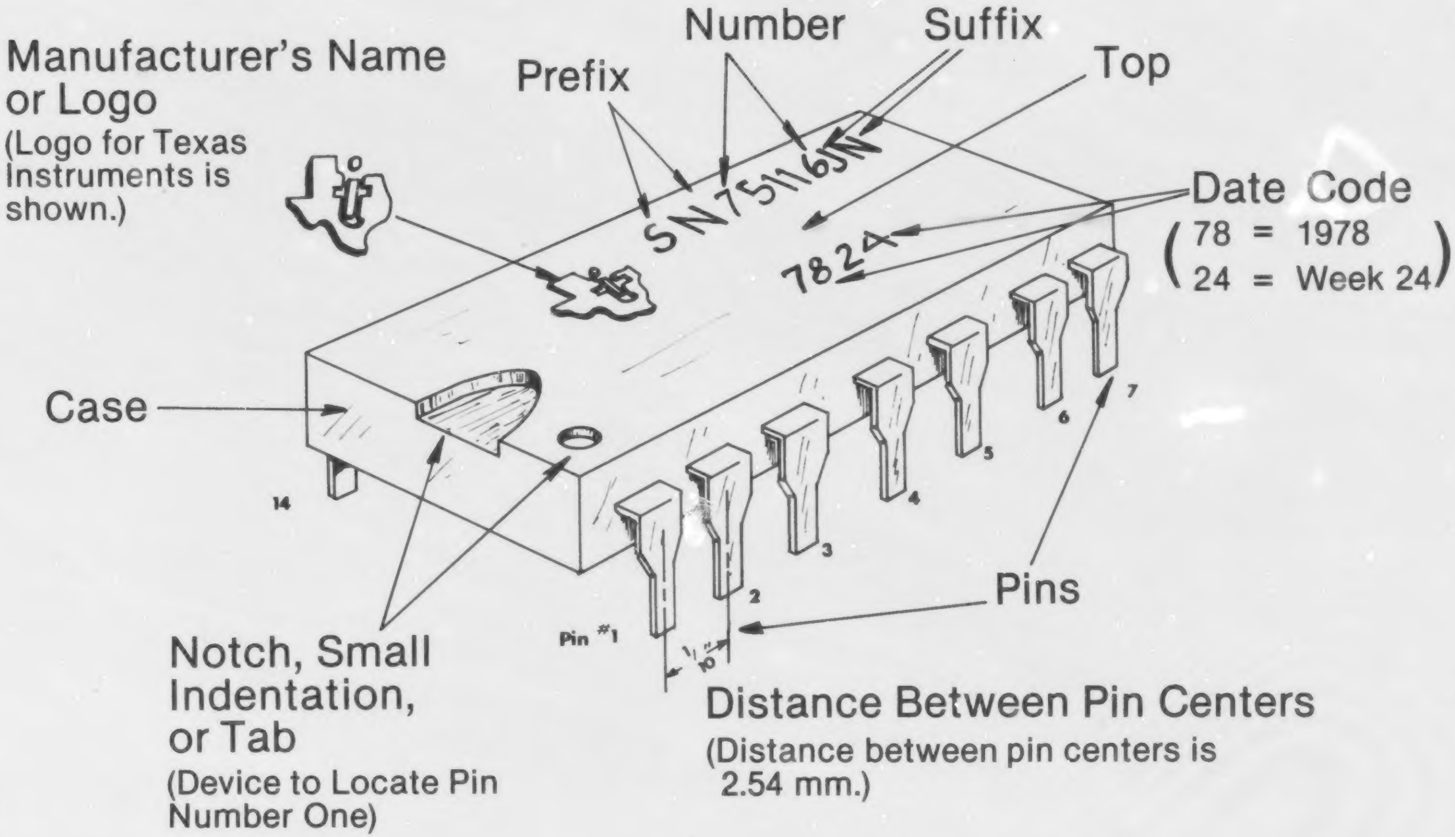


Fourteen-Pin Dual In-Line (DIP)

Ten-Pin Case (TO-100)



Features of a Typical Dual In-Line Package Integrated Circuit


Manufacturer's Name or Logo
(Logo for Texas Instruments is shown.)
Prefix
Number
Suffix
Top
SN75116JN
7824
Date Code
78 = 1978
24 = Week 24
Case
14
Pin #1
2
3
4
5
6
7
Pins
1/10"
Notch, Small Indentation, or Tab
(Device to Locate Pin Number One)
Distance Between Pin Centers
(Distance between pin centers is 2.54 mm.)

TM #2

GIE - 343-B

INTEGRATED CIRCUITS
UNIT V

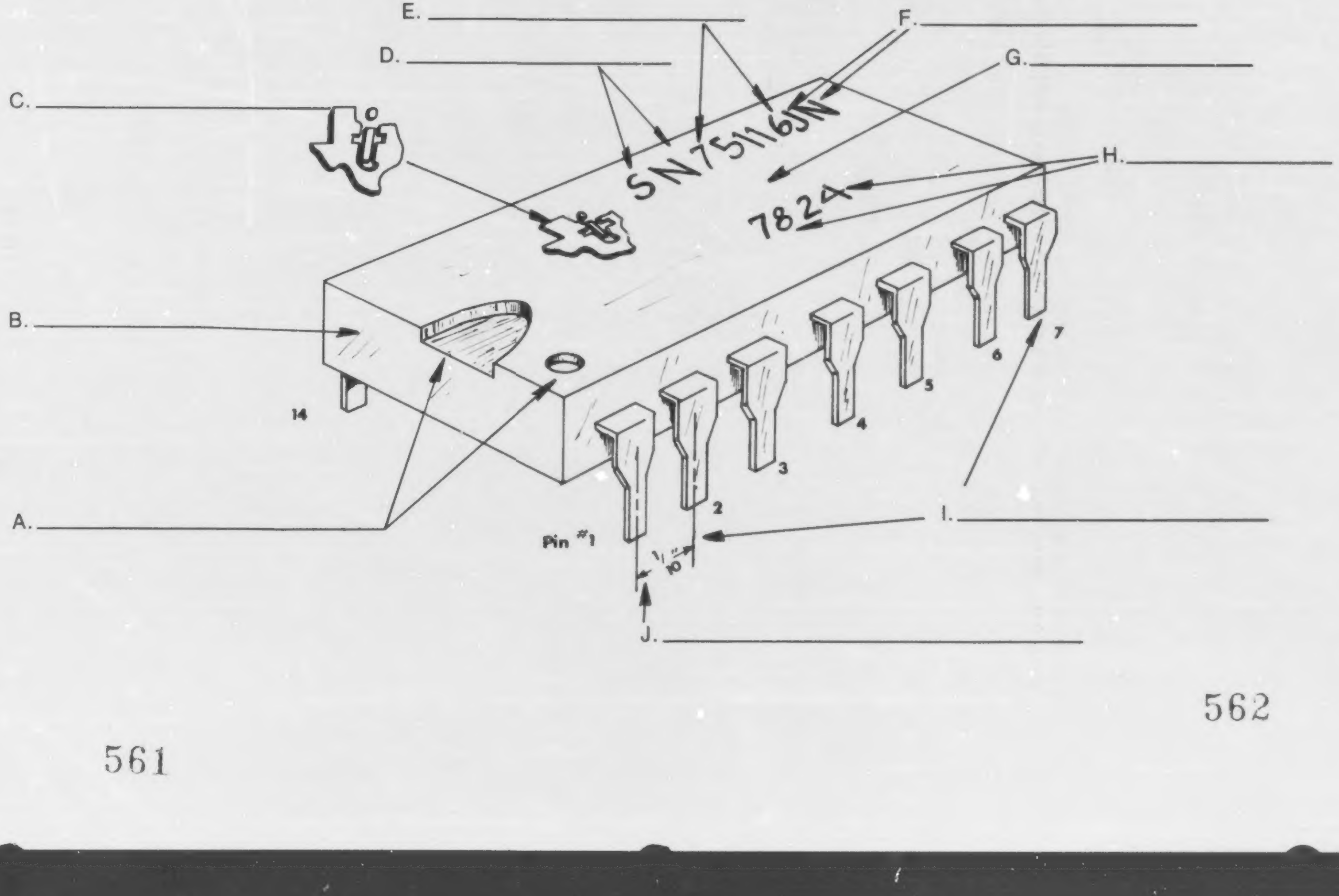
ASSIGNMENT SHEET #1 — LABEL FEATURES OF A TYPICAL DUAL IN-LINE PACKAGE INTEGRATED CIRCUIT

NAME ______________________________ SCORE ______________

Integrated circuits have become one of the major components an electronics technician will be using. As such, each technician should be able to identify integrated-circuit features.

Label the features of the dual in-line package integrated circuit on the following page. Do not refer to Transparency #2.

ASSIGNMENT SHEET #1


E. ____________________
F. ____________________
D. ____________________
G. ____________________
C. ____________________
SN75116JN
H. ____________________
7824
B. ____________________
7
6
5
4
3
2
14
Pin #1
A. ____________________
I. ____________________
1/10"
J. ____________________

INTEGRATED CIRCUITS
UNIT V

ASSIGNMENT SHEET #2 — USE DATA MANUALS TO LABEL INTEGRATED-CIRCUIT NUMBER-ONE PIN

NAME ______________________________ SCORE ____________

In order to be able to work with integrated circuits, the electronics technician must know how to use data manuals to determine the type of integrated circuit being used and the correct pins to connect in the circuit.

Using data manuals supplied by your instructor, determine the pin configuration of the following ICs. Draw the IC in the space provided and indicate pin number one.

A. μA741

B. TO-100

INTEGRATED CIRCUITS
UNIT V

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

A. Notch, small indentation, or tab

B. Case

C. Manufacturer's name or logo

D. Prefix

E. Number

F. Suffix

G. Top

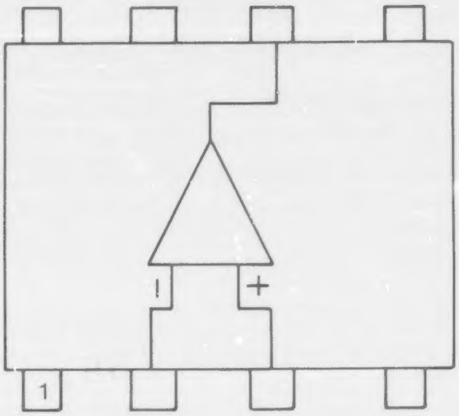
H. Date code

I. Pins

J. Distance between pin centers

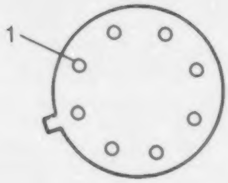
Assignment Sheet #2

A. μA741



ANSWERS TO ASSIGNMENT SHEETS

B. TO-100



INTEGRATED CIRCUITS
UNIT V

JOB SHEET #1 — ANALYZE THE INTEGRATED-CIRCUIT OPERATIONAL AMPLIFIER

I. Equipment and materials

- A. Two regulated direct-current or dual-output power supplies
- B. Function generator
- C. Dual-trace oscilloscope
- D. Operational amplifier, 741 or equivalent
- E. Two resistors, 1 kohm
- F. Resistor, 10 kohm
- G. Resistor, 5 kohm
- H. IC data book
- I. Breadboard
- J. Various test leads

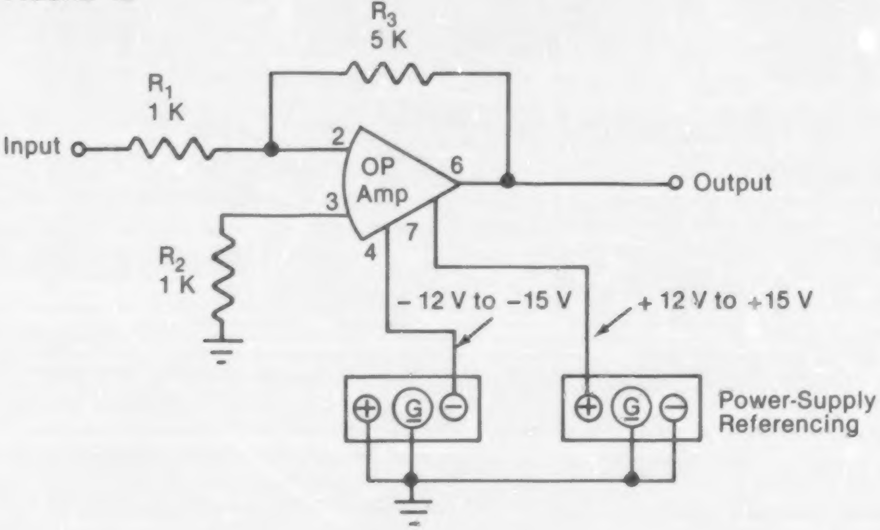
JOB SHEET #1

II. Procedure

A. Construct circuit as shown in Figure 12

(NOTE: Set the power supply voltages and turn the power supplies to standby. Have the instructor check circuit before connecting power supply to circuit.)

FIGURE 12



R_3
5 K
R_1
1 K
Input
2
OP
Amp
6
Output
3
7
4
R_2
1 K
– 12 V to –15 V
+ 12 V to +15 V
⊕
G
⊖
⊕
G
⊖
Power-Supply
Referencing

B. Adjust function generator for minimum amplitude and a frequency between 20 hertz and 20 kilohertz

C. Calculate amplifier gain; record

(NOTE: Gain of the operational amplifier is calculated by dividing the feedback resistance by the input resistance.)

Amplifier gain = ________________________________

D. Turn on V_{CC} power supplies

E. Connect function generator to input of amplifier

F. Connect one channel of oscilloscope to input signal; connect other channel to amplifier output

G. Adjust amplitude of function generator for a 10-volt peak-to-peak amplifier output signal

JOB SHEET #1

H. Measure amplifier's input voltage

I. Calculate the voltage gain of the operational amplifier by using the voltage values in step G

Voltage gain = ____________________

J. Do the gain calculations in step C compare with those of step I? ________

K. Replace resistor R3 with 10-kohm resistor

L. Calculate voltage gain of this circuit; record

Voltage gain = ____________________

M. Measure input signal; record

Input signal = ____________________

N. Measure output signal; record

Output signal = ____________________

O. Using the measurements above, calculate actual voltage gain of operational amplifier

(NOTE: The ratio between the feedback resistor and the input resistor will determine the gain of the amplifier.)

Voltage gain = ____________________

P. Using signals on oscilloscope, compare input signal with output signal

Q. Is amplifier an inverting or noninverting amplifier? ________________

R. Turn off function generator

S. Switch input connections of R1 and R2

(NOTE: R1 should now be connected to ground, and the input should be applied to R2. Have the instructor check the circuit.)

T. Turn on function generator

U. Using signals on oscilloscope, compare input signal with output signal

V. Is amplifier an inverting or noninverting amplifier? ________________

(NOTE: Discuss your results with the instructor.)

JOB SHEET #1

W. Disconnect equipment

X. Clean work area; put away equipment and materials

INTEGRATED CIRCUITS
UNIT V

JOB SHEET #2 — CONSTRUCT A TIMER CIRCUIT USING A 555 INTEGRATED CIRCUIT

I. Equipment and materials

- A. Type 555 integrated circuit
- B. Regulated 5-volt laboratory power supply
- C. Light-emitting diode
- D. Breadboard and connector wires
- E. Resistor, 150 ohm, 1/4 watt
- F. Resistor, 1 kohm
- G. Resistor, 1 megohm
- H. Resistor, 1.8 kohm
- I. Capacitor, 1 microfarad
- J. Capacitor, 5 microfarad
- K. Capacitor, 0.001 microfarad
- L. Oscilloscope
- M. Stopwatch or watch displaying seconds

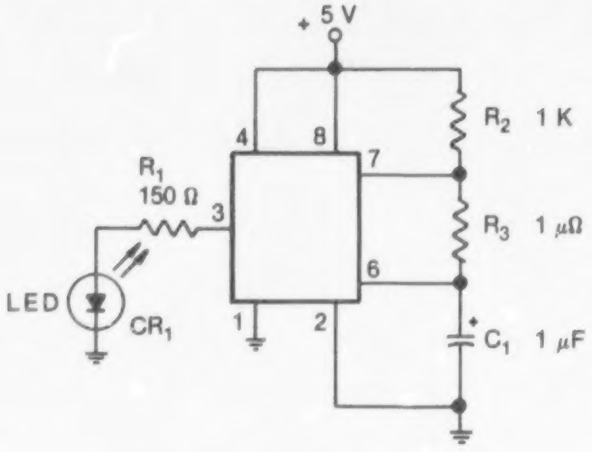
JOB SHEET #2

II. Procedure

A. Construct circuit as shown in Figure 13

(NOTE: Have the instructor check the circuit before applying power.)

FIGURE 13



B. Apply power to the circuit

C. Observe the light-emitting diode (LED); count the number of times it comes on in one minute; record

(NOTE: The LED should pulse at a rate of about forty-four flashes per minute. This represents a frequency of 0.73 hertz. Frequency (f) can be calculated using the formula

$$f = \frac{1.443}{(R_1 + 2R_2)\,C}.)$$

LED pulse rate = ______________________________

D. Disconnect power

E. Replace capacitor with a 5-microfarad capacitor

F. Calculate frequency for the new circuit; record

Frequency = ______________________________

G. Reconnect power

JOB SHEET #2

H. Observe the LED and count the number of flashes in one minute; record

LED pulse rate = ______________________________

I. Disconnect power

J. Replace capacitor with 0.001-microfarad capacitor

K. Connect oscilloscope to pin 3 of the 555 integrated circuit

L. Calculate frequency of the new circuit

Frequency = ______________________________

M. Reconnect power

N. Observe the LED

(NOTE: The LED appears to be glowing steadily. However, it is actually pulsing at a frequency of approximately 720 hertz or a complete cycle every 1.4 milliseconds. The human eye can only detect about sixteen changes in the light per second; therefore, the LED appears to be on continuously.)

O. Disconnect power

P. Replace R2 with 1.8-kohm resistor

Q. Reconnect power

R. Observe wave forms

(NOTE: Discuss your results with the instructor.)

S. Disconnect equipment

T. Clean work area; put away equipment and materials

INTEGRATED CIRCUITS
UNIT V

TEST

NAME ______________________________ SCORE ______________

1. Match terms associated with integrated circuits to their correct definitions. Write the correct numbers in the blanks. Terms and definitions continue on the following page.

_____a. Component composed of one functional element as opposed to an integrated-circuit device composed of many elements

_____b. Base material of an integrated-circuit chip upon which the circuitry is formed

_____c. Device constructed of multiple segments of semiconductor materials and junctions containing the equivalent function of such discrete devices as transistor and diode junctions, resistors, and capacitors

_____d. Component that operates at any voltage level within a range

_____e. Having two voltage levels of inputs and outputs

_____f. Component that operates at specific voltage levels, switching outputs between those levels according to specific input levels

_____g. Devices containing the composite of thousands of components in a small, integrated form

_____h. Devices containing the composite of hundreds of components in a small, integrated form

_____i. Component that has the same gain or reaction to the input over the operating range regardless of frequency or environmental factors such as temperature and humidity

_____j. Devices containing the composite of several discrete components in a small, integrated form

1. Integrated circuit
2. Substrate
3. Discrete device
4. Digital device
5. Binary
6. Analog device
7. Very large-scale integration
8. Small-scale integration
9. Linear device
10. Large-scale integration

TEST

______k. Devices containing the composite of dozens of discrete components in a small, integrated form

______l. Circuitry, wiring, and devices of an electronic instrument or computer

______m. Integrated circuit

______n. Device in which discrete components or integrated circuits are integrated into a package

______o. Device in which active elements (such as transistors) and passive elements (such as resistors) are integrated into a continuous single component on a single substrate

11. Medium-scale integration
12. Hardware
13. Chip
14. Monolithic integrated circuit
15. Hybrid integrated circuit

2. Match abbreviations and acronyms associated with integrated circuits to their correct interpretations. Write the correct numbers in the blanks. Abbreviations and acronyms and their interpretations continue on the following page.

______a. Integrated circuit

______b. Metal-oxide semiconductor field-effect transistor

______c. Very large-scale integration

______d. Direct-coupled transistor logic

______e. Dual in-line package

______f. Drain supply voltage

______g. Collector supply voltage

______h. Resistor/transistor logic

______i. Diode/transistor logic

______j. Complementary metal-oxide semiconductor

______k. n-type metal-oxide semiconductor

______l. Metal-oxide semiconductor

______m. Small-scale integration

______n. Emitter-coupled logic

1. IC
2. SSI
3. DIP
4. V_{CC}
5. VLSI
6. RTL
7. DTL
8. DCTL
9. ECL
10. MOS
11. CMOS
12. NMOS
13. MOSFET
14. V_{DD}

TEST

______o.	Source supply voltage	15.	V_{SS}
______p.	p-type metal-oxide semiconductor	16.	LSI
______q.	Medium-scale integration	17.	PMOS
______r.	Large-scale integration	18.	MSI
______s.	Transistor/transistor logic	19.	TTL, T^{2}L
______t.	Printed circuit board	20.	IIL,I^{2}L
______u.	Integrated injection logic	21.	PCB
______v.	Military specification	22.	mil spec

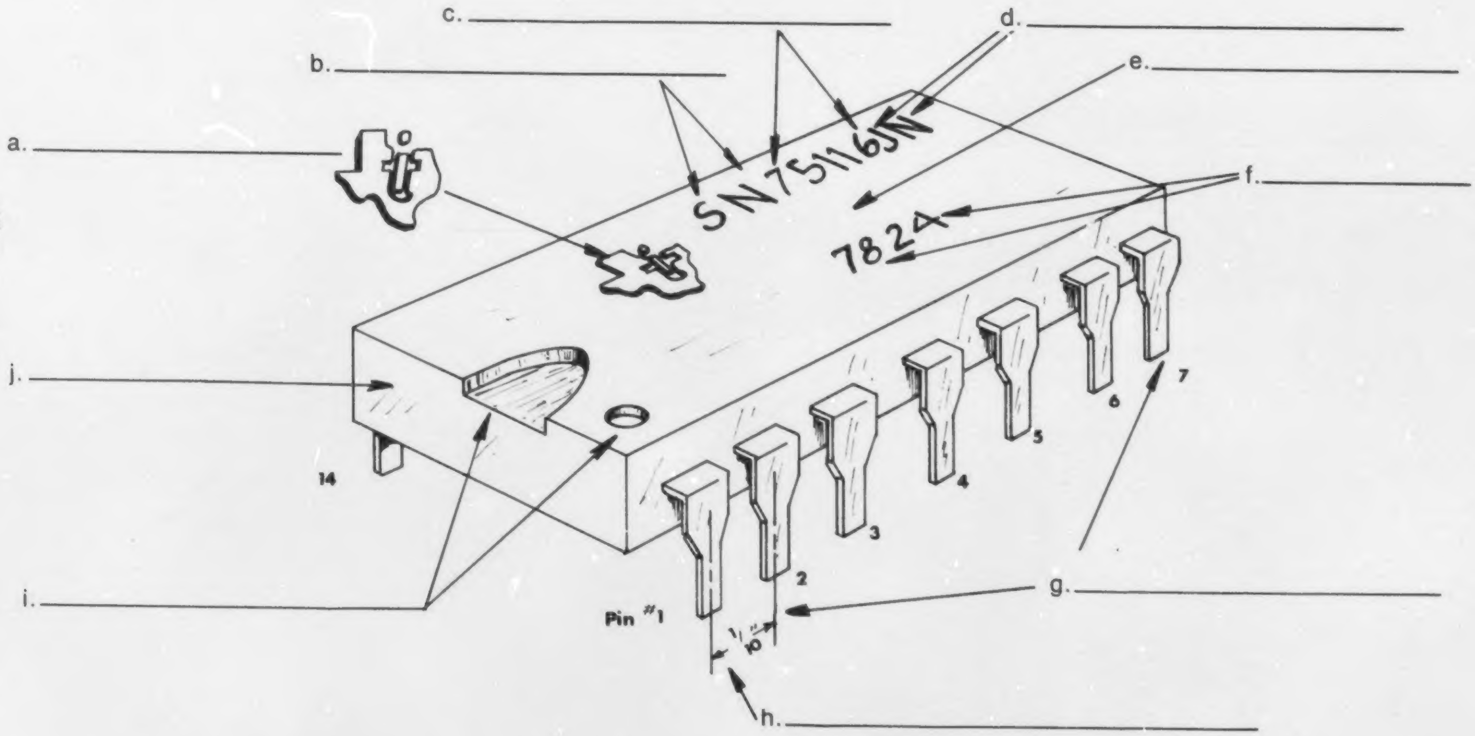
3. Name commonly used integrated-circuit packages.

a. ______________________________

b. ______________________________

TEST

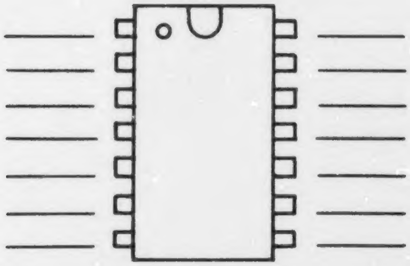
4. Label features of a typical dual in-line package integrated circuit.


a. ____
b. ____
c. ____
d. ____
e. ____
f. ____
g. ____
h. ____
i. ____
j. ____
SN75116JN
7824
14
Pin #1
2
3
4
5
6
7
1/10"

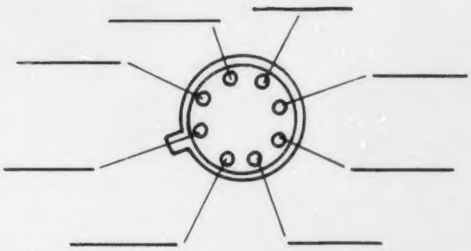
TEST

5. Label number-one pin on integrated circuits. For each of the illustrations below, write a "1" in the correct blank.

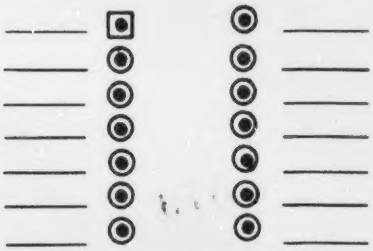
a.



b.

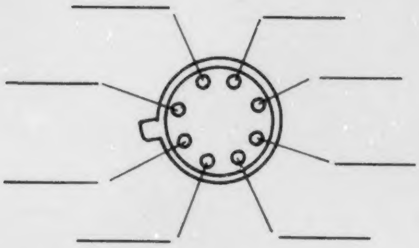


c.



TEST

d.



6. Name the principal elements contained in integrated circuits.

a.

b.

c.

d.

e.

7. State advantages of integrated circuits as compared to discrete components in equivalent circuitry.

a.

b.

c.

d.

e.

f.

TEST

8. Match integrated-circuit troubleshooting equipment to their correct applications. Write the correct numbers in the blanks.

______a. Used to install and remove DIP ICs without bending pins

______b. Used to view several IC inputs and outputs at a time; displays digital codes, timing-diagram wave forms, or digital maps of sequences

______c. Used to detect high or low digital state of inputs and outputs

______d. Used to heat components while troubleshooting to find intermittent failures due to heat-sensitive integrated circuits

______e. Used to check IC leads for voltage

______f. Used to clamp on to DIP ICs to make oscilloscope and other probe measurements easier

______g. Used to trace current paths through circuits

1. Heat gun
2. Digital IC logic probe
3. IC voltage probe
4. IC test clip
5. DIP insertion and extraction tools
6. Logic analyzer
7. IC current probe

9. Distinguish between linear integrated-circuit applications and digital integrated-circuit applications. Write an "L" in the blanks before linear integrated-circuit applications and a "D" in the blanks before digital integrated-circuit applications.

______a. Memory circuits

______b. Amplifiers

______c. Counters

______d. Voltage control

______e. Analog control

______f. Logic circuits

______g. Interface circuits

TEST

10. List guidelines for technicians to follow when working with integrated circuits.

    a. ________________

    b. ________________

    c. ________________

    d. ________________

    e. ________________

    f. ________________

    g. ________________

    h. ________________

    i. ________________

    j. ________________

    k. ________________

(NOTE: Test question 11 lists the job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

11. Demonstrate the ability to

    a. Analyze the integrated-circuit operational amplifier.

    b. Construct a timer circuit using a 555 integrated circuit.

INTEGRATED CIRCUITS
UNIT V

ANSWERS TO TEST

1.
- a. 3
- b. 2
- c. 1
- d. 6
- e. 5
- f. 4
- g. 7
- h. 10
- i. 9
- j. 8
- k. 11
- l. 12
- m. 13
- n. 15
- o. 14

2.
- a. 1
- b. 13
- c. 5
- d. 8
- e. 3
- f. 14
- g. 4
- h. 6
- i. 7
- j. 11
- k. 12
- l. 10
- m. 2
- n. 9
- o. 15
- p. 17
- q. 18
- r. 16
- s. 19
- t. 21
- u. 20
- v. 22

3.
- a. Dual in-line
- b. Case

4.
- a. Manufacturer's name or logo
- b. Prefix
- c. Number
- d. Suffix
- e. Top
- f. Date code
- g. Pins

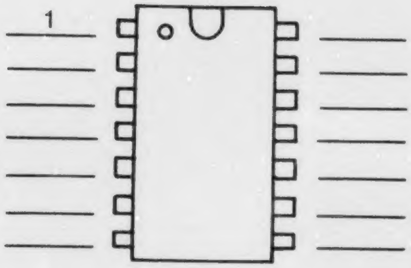
ANSWERS TO TEST

h. Distance between pin centers

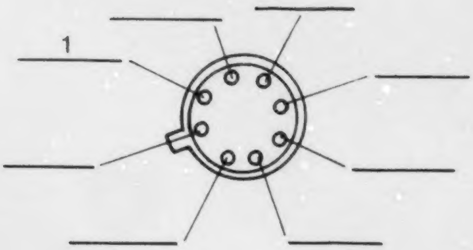
i. Notch, small indentation, or tab

j. Case

5. a.

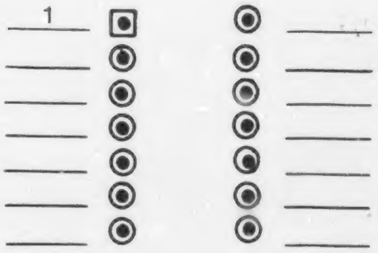


b.

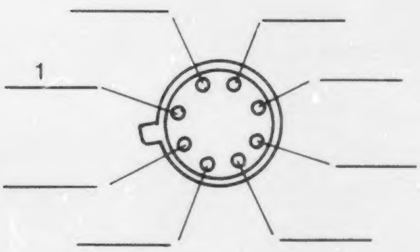


ANSWERS TO TEST

c.



d.



6. a. Transistors

b. Diodes

c. Resistors

d. Capacitors

e. Photosensitive elements

ANSWERS TO TEST

7. a. Are more reliable
   b. Generally require lower power
   c. Are less costly
   d. Are smaller, more compact, and lighter in weight
   e. Are simpler and faster to design and fabricate
   f. Provide simplified compatibility of interconnecting circuitry

8. a. 5
   b. 6
   c. 2
   d. 1
   e. 3
   f. 4
   g. 7

9. a. D
   b. L
   c. D
   d. L
   e. L
   f. D
   g. L

10. a. Store ICs in antistatic containers
    b. Wear static-grounded wrist strap
    c. Use low-wattage soldering iron
    d. Avoid overheating component when soldering

ANSWERS TO TEST

e. Do not use acid solder, chloride fluxes, or paste fluxes

f. Do not remove ICs or PCBs with power on

g. Do not drop or subject ICs to mechanical shock

h. Do not apply signals to inputs when power is off

i. Consult reference manual for proper voltages and connection requirements

j. Use special test clips to avoid shorting between terminals

k. Do not use analog multimeters to test for shorts and open circuits

11. Performance skills evaluated to the satisfaction of the instructor